REPORT NUMBER 158

MAY 1965

AIRCRAFT FABRICATION, ASSEMBLY, AND INSPECTION

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REPORT NUMBER 158

AIRCRAFT FABRICATION, ASSEMBLY, AND INSPECTION

XV-5A Lift Fan
Flight Research Aircraft

Contract No. DA 44-177-TC-715

May 1965

ADVANCED ENGINE AND TECHNOLOGY DEPARTMENT
GENERAL ELECTRIC COMPANY
CINCINNATI, OHIO 45215

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1.0 INTRODUCTION

This report presents a summary of the XV-5A aircraft fabrication, assembly and inspection history and is submitted in accordance with Government Contract DA 177-TC-715. Ryan Aeronautical Company was responsible for fabrication of two XV-5A Lift-Fan Flight Research Aircraft with the exception of the General Electric Propulsion System. Manufacturing activities began in December 1961 and were completed during March 1964. Parts support was accomplished throughout the flight test program.

The XV-5A is a two engine lift-fan powered, mid-wing V/STOL aircraft. The lift system arrangement consists of two J85-GE5 turbojet engines with diverter valves pneumatically connected to General Electric wing fans and located in each wing, and one General Electric pitch fan. The aircraft has provisions for one pilot and one observer located side-by-side. The aircraft incorporates an integrated instrumentation system.

Geometric Summary

Design Empty Weight	8063 pounds
Design Gross Weight	9200 pounds
Maximum Gross Weight	12500 pounds
Overall Length	44.52 feet
Overall Height	14.75 feet
Wing Span	29.8 feet
Wing Area	260.3 square feet
Horizontal Tail Area	52.8 square feet
Vertical Tail Area	50.99 square feet
Installed Fuel Tank Capacity	3250 pounds
Fan Diameters	
Wing Fans	62.5 inches
Nose Fan	36 inches

A cut-away view of the XV-5A is shown in Figure 1.

This report presents a general summary of the aircraft tooling, manufacturing, assembly, and inspection programs. Development of the manufacturing policies up to the time of delivery of the aircraft to Edwards Air Force Base is discussed in the chronological order of aircraft manufacturing events including certain interesting manufacturing techniques and material applications.

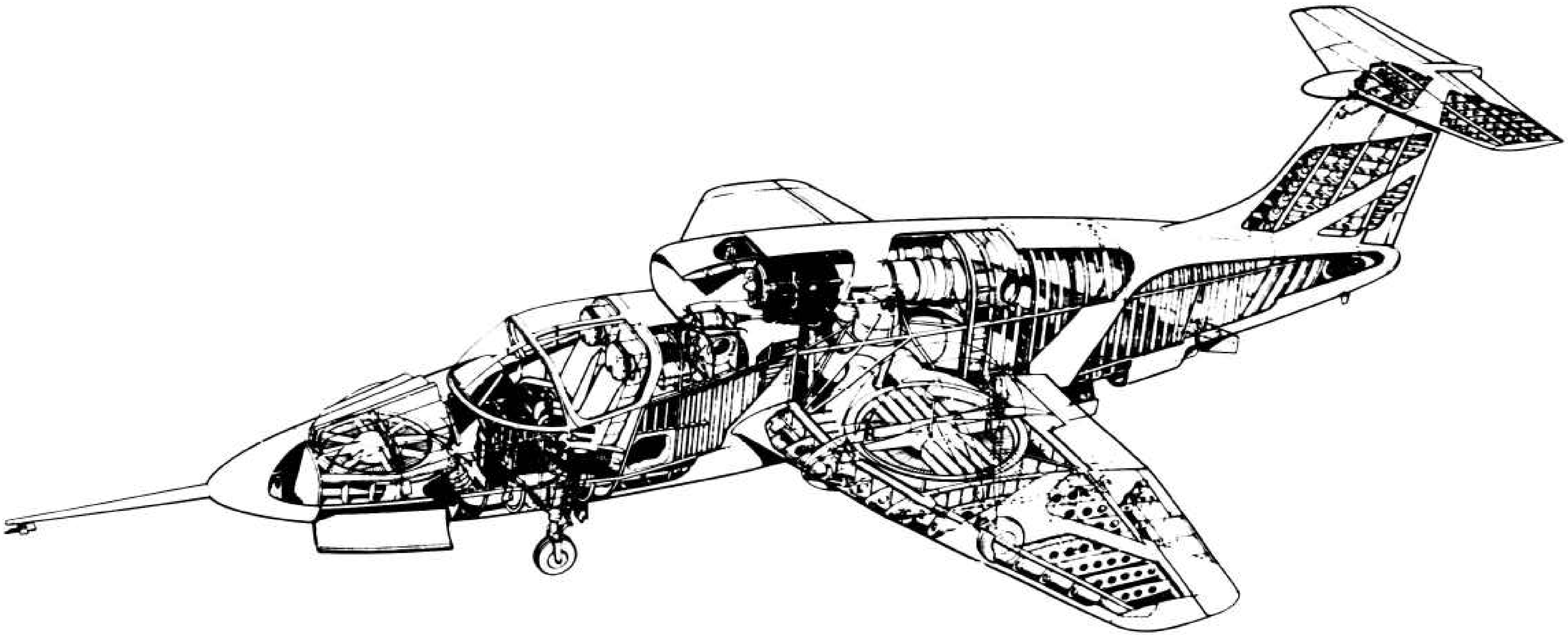

Figure 1   XV-5A Cutaway View

2.0 XV-5A TOOLING PROGRAM

2.1 GENERAL

The XV-5A tools were planned and designed on the basis of fabricating two aircraft only. Although this dictates, to a large degree, use of disposable tooling, commonly referred to as soft tooling, precision of dimensions was emphasized as a part of the overall XV-5A minimum weight policy. Because of the few details per tool, interchangeability requirements were relaxed, except where otherwise specified by the Engineering Group. Coordination tooling was held to a minimum as were tooling masters. Fit-on-assembly procedures were followed wherever possible.

2.2 TOOL ENGINEERING

The Tooling Project Engineer controlled the project within the Ryan Production Engineering Department, and was the coordinator between Engineering and Production. This single point of control greatly assisted the XV-5A manufacturing program since engineering work was coordinated with fabrication requirements in advance of engineering release. Tool engineering personnel were located with the Engineering Design Group to resolve any fabrication problems early in the development of the design.

2.3 TOOL PLANNING

Detail tool planning was written on all parts and assemblies to assure inclusion of specified processing and inspection requirements.

2.4 TOOL DESIGN

Tools were designed with consideration of the low quantity of parts to be manufactured. Disposable tooling was utilized as much as possible. Cost effectiveness determined the sophistication level of tools based on fabrication and assembly time. In general, most fabrication tools were considered expendable, and assembly tools considered reusable.

2.5 TOOL MANUFACTURING

All tools were manufactured in accordance with tooling policies established for the project and to applicable shop standards. Many shop aids were fabricated in the XV-5A assembly building, but the Ryan tool room made large items such as special fixtures, hydroform blocks, masters, etc. The following policies were maintained in providing detail tools:

- Flat pattern templates were used for all details except where the part configuration could be obtained directly from engineering drawings.
- Form block templates were photographed on 0.40" aluminum, and cut per standard procedures.
- Blanking dies and router blocks were utilized only when approximately 20 parts per ship were required. Small quantities were hand-trimmed in the assembly area.
- Hydropress blocks were made to standard springback allowances, recognizing that some parts had to be hand worked due to sprinback variations. Since only two aircraft were fabricated, hydropress block tool proofing would exceed by far the cost of hand working formed parts to their proper contour. The blocks for aluminum parts were made of Masonite and/or aluminum. Production materials, such as titanium, requiring hot forming, were made on Meehanite blocks.
- Drop hammer dies were used on parts having severe double contours such as the cross-over duct skins. Dies cast to shrink patterns with lead punches were used exclusively.
- Skin stretch press dies were avoided wherever possible, except where severe double contours were required. Skins having mild double contours were bumped on the Yoder Hammer, then fitted and trimmed on assembly.
- Drill jigs in the form of simple drill plates were provided. A few transfer drill plates were fabricated for parts such as the wing to fuselage interfaces, ejection seat rails to bulkhead, etc. Wherever possible, precision drilling was accomplished upon assembly where both parts were drilled simultaneously, utilizing pilot holes.

- **Holding fixtures for machining details were only considered where size and/or shape, or close tolerances, made standard setups impossible.**

3.0 MANUFACTURING PROGRAM

3.1 FABRICATION OF AIRFRAME HARDWARE

Sheet metal parts with straight flanges were power sheared and brake formed. Hydroform parts were cut to layouts. Power shears and Strippet fabricators were used wherever possible. Hand work corrected spring-back variations of hydroformed parts. Coordination holes were considered on all loft parts such as bulkheads, frames, and spars to locate non-critical brackets, etc.

Skins were rolled on the Farnam Rolls, bumped on the Yoder Hammer, or stretched. All skins were fitted and trimmed during the assembly operation.

Machined parts were laid out by hand using temporary setups. Boring mills were utilized wherever possible and where maintenance of accuracy and close tolerances was required. Figure 2 shows the forward spar being rough machined as a typical example of a temporary setup and the use of boring mills.

Chem-milling was used extensively throughout the airframe as a means of achieving weight reduction without sacrifice of strength. Chem-milling processes were utilized on magnesium, aluminum, and titanium materials. Figure 3 shows the end rib of the pitch fan thrust reverser door which was chem-milled from titanium plate. Wall thicknesses of this rib were too thin for conventional machining because of tool pressure breakthrough.

The fabrication philosophy, common as well to both design and assembly, was to (1) fabricate flightworthy details, and (2) minimize weight. A few examples of weight reduction are presented in Figures 2 and 3 to illustrate maintenance of this overall policy.

3.1.1 Wing Fan Doors

The wing fan doors represented a challenge to current state-of-the-art of reinforced Fiberglas structures. These assemblies required minimum weight plus high strength. The right and left hand doors were fabricated in one unit. Prior to installing hinges and other hard points, the doors

Figure 2 Wing Spar Rough Machining Operation

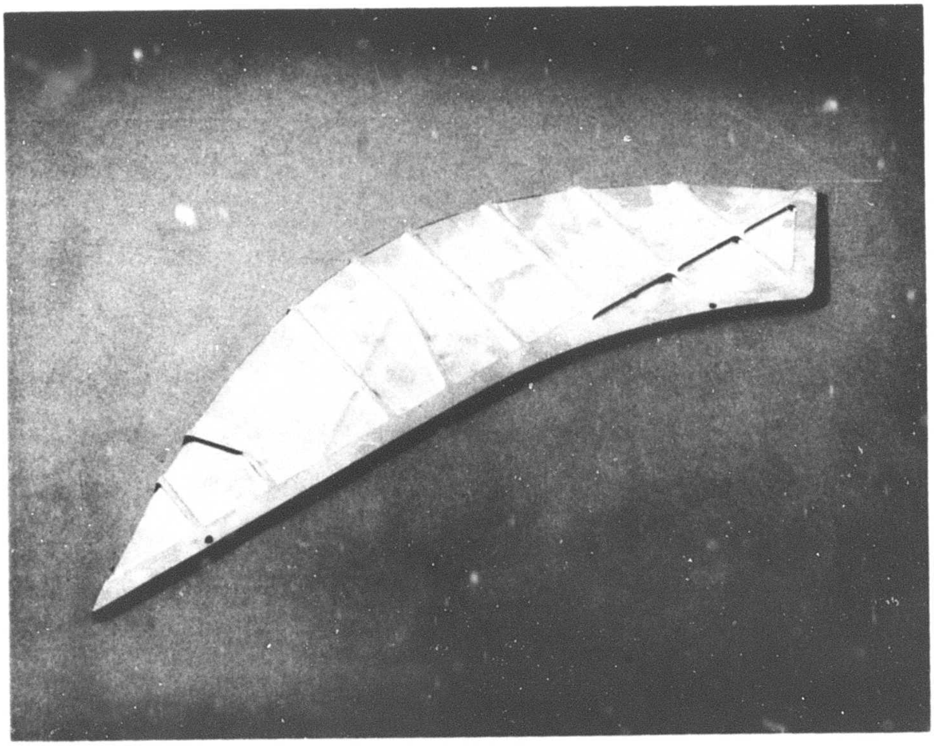

Figure 3 Thrust Reverser Door End Rib

were separated. Figure 4 shows the honeycomb core being machined to the proper contour, Figure 5 shows the core after machining was complete. The outer skin was applied and bonded as in Figure 6. A vacuum process was utilized to maintain exact bonding between the skins and core, (Figure 7). The inside skin was then applied, (Figure 8) and the entire assembly cured in a medium temperature oven. The lower skin was fabricated with high temperature phenolic resins to resist the temperature environment of the fan cavity. The door was then trimmed and hinge and latch points installed (Figure 9). Figure 10 shows the completed door being installed on the aircraft.

3.1.2 Spar Machining

The XV-5A spars were machined from solid aluminum billets (Figure 11), utilizing a tracer controlled boring mill. Spar master patterns were fabricated in the tool shop as shown in Figure 12. The boring mill duplicated these patterns from the solid billet. Figure 13 shows a rough machined forward spar being finished machined.

3.1.3 Engine Inlet

The inlet was fabricated entirely of reinforced Fiberglas. The outer shell, (Figure 14) was laid up over a plaster pattern. Similarly, the engine induction ducts were laid up over a plaster pattern. These units were bonded into one assembly, as shown in Figure 15. This unit is an impressive achievement in the use of reinforced Fiberglas materials. The pitch fan inlet duct assembly is shown in Figure 16 as viewed from the bottom side. This assembly was also fabricated of reinforced Fiberglas laminates with a significant weight saving relative to conventional aluminum construction. A typical example of a plaster master for plastic laminated layups is shown in Figure 17.

Another significant use of reinforced Fiberglas laminates is the cockpit canopy shown in Figure 18. The frame of the canopy utilizes U-shaped channels filled with low density plastic foam.

The engine cover fairing was another unique assembly. This assembly (Figure 19) was constructed of an aluminum-faced honeycomb sandwich. Tooling development was responsible for successfully bonding the unit without wrinkles in the inner (shrink) skin. It is estimated that use of a honeycomb sandwich for this unit, and the use of reinforced Fiberglas laminate for the engine inlet duct, saved 40 pounds as compared with conventional aluminum skin and frame construction.

Figure 4 Honeycomb Core - Wing Fan Door

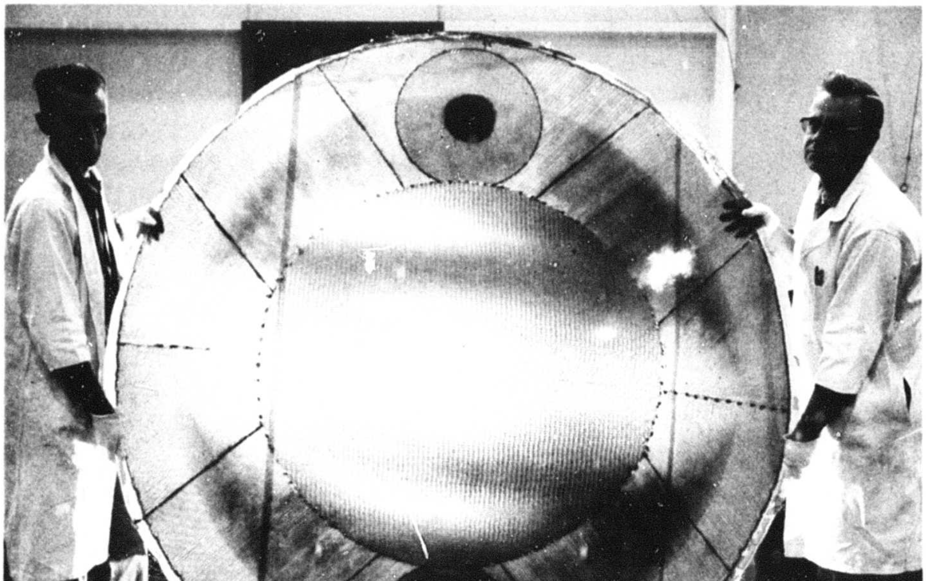

Figure 5 Honeycomb Core Finish Machine

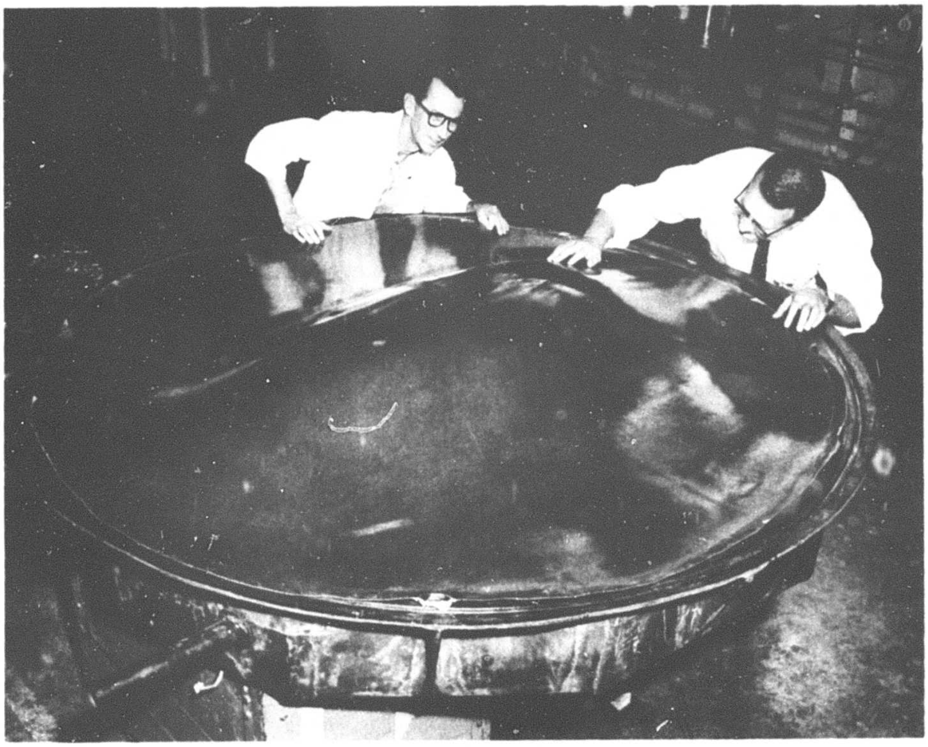

Figure 6 Outer Door Skin Application

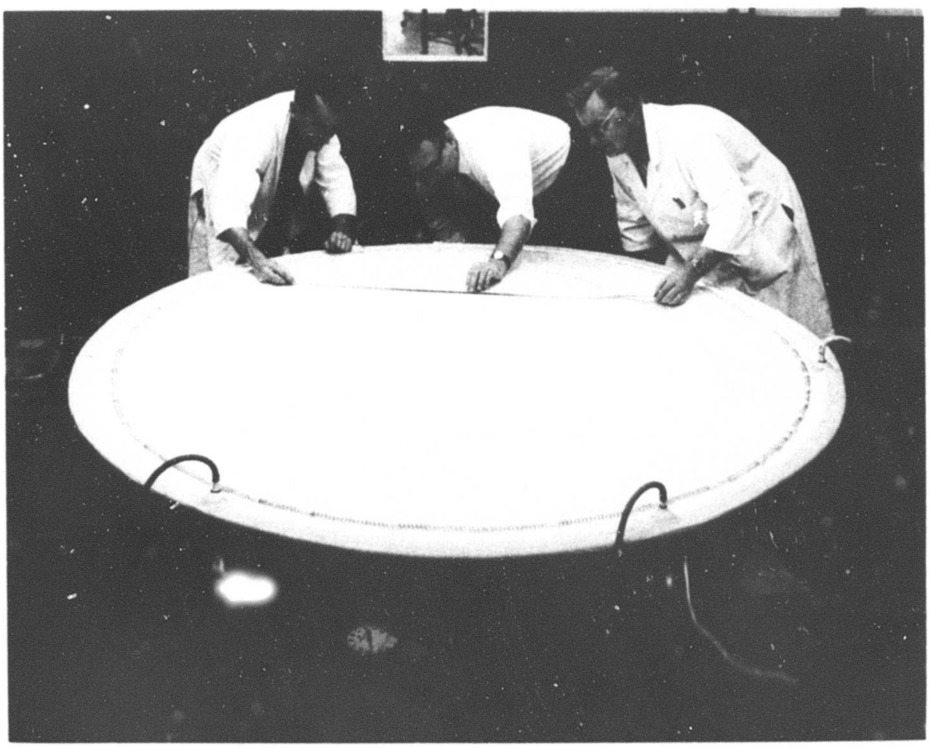

Figure 7 Vacuum Bonding Fixture - Door Skin

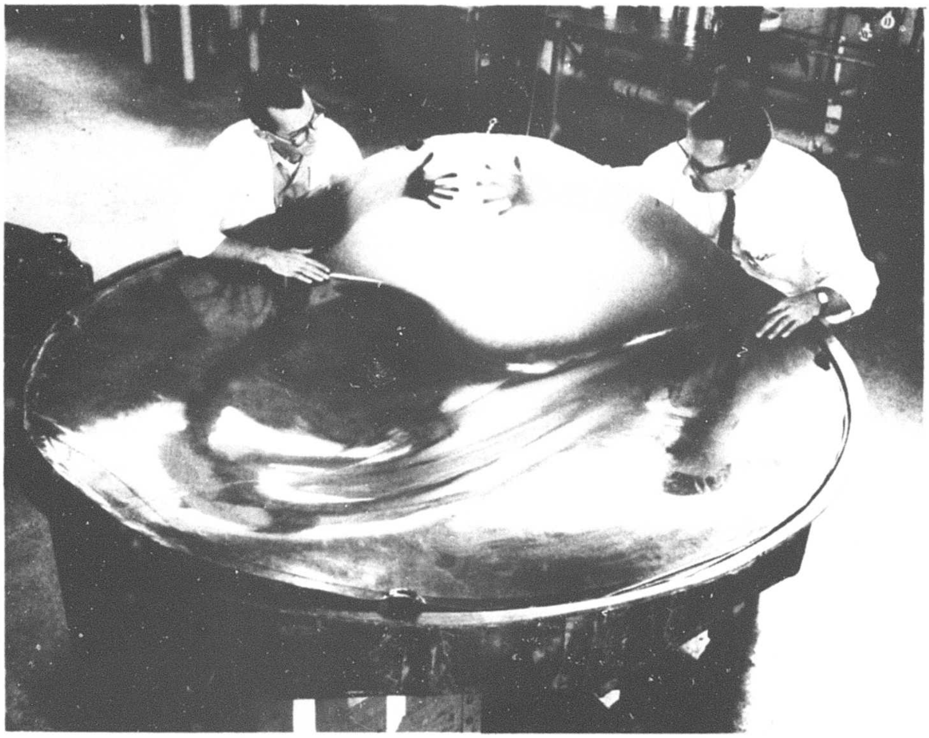

Figure 8   Inner Door Skin Application

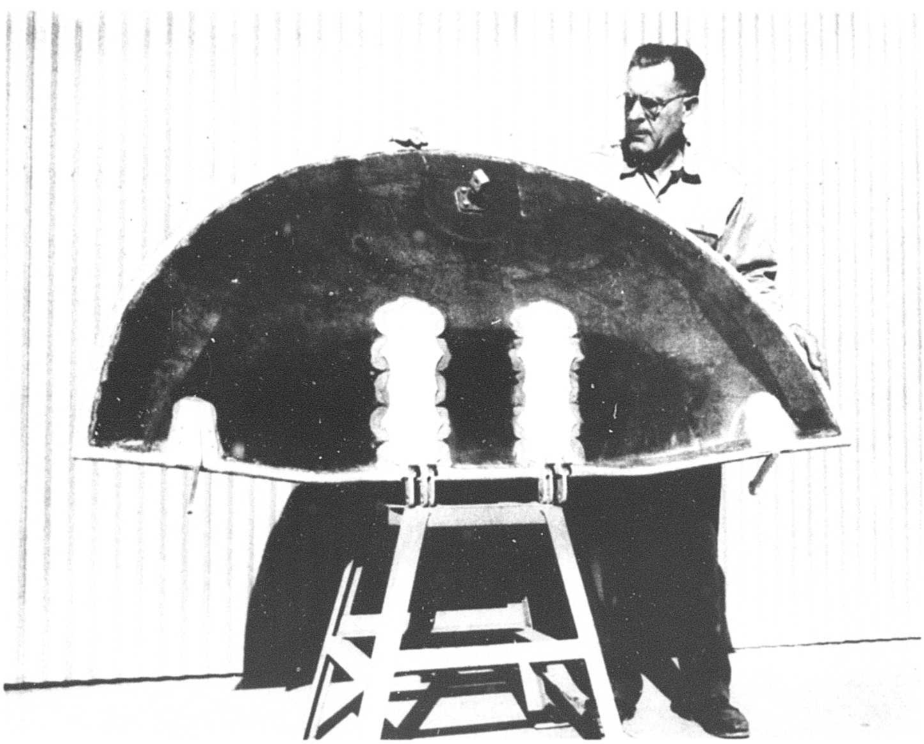

Figure 9   Door Hinge and Latch Fittings Installed

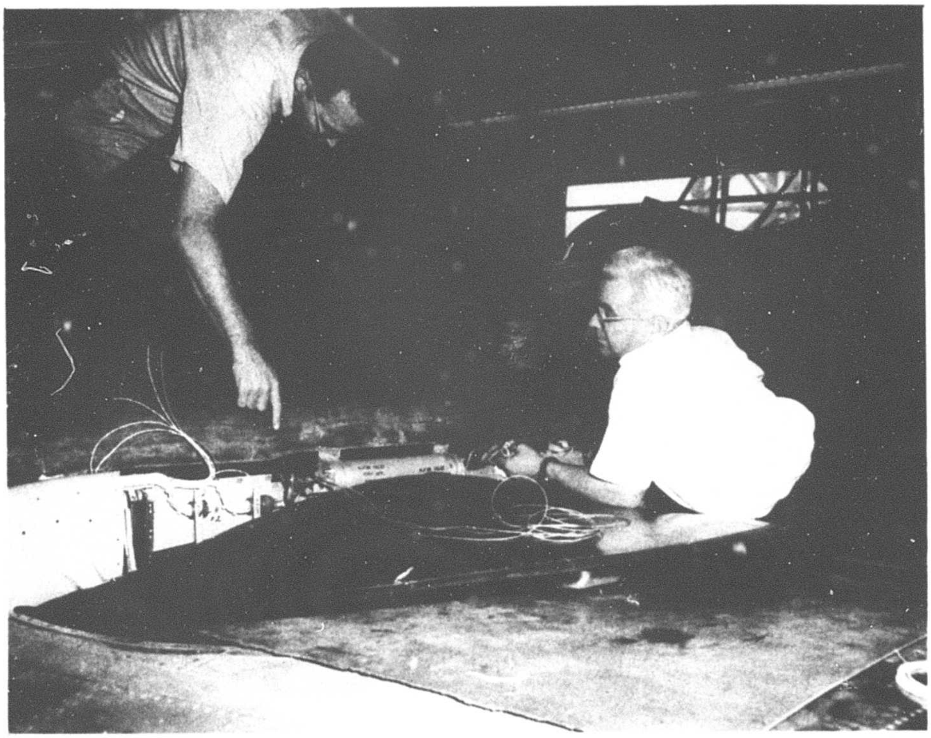

Figure 10 Wing Fan Door Installation

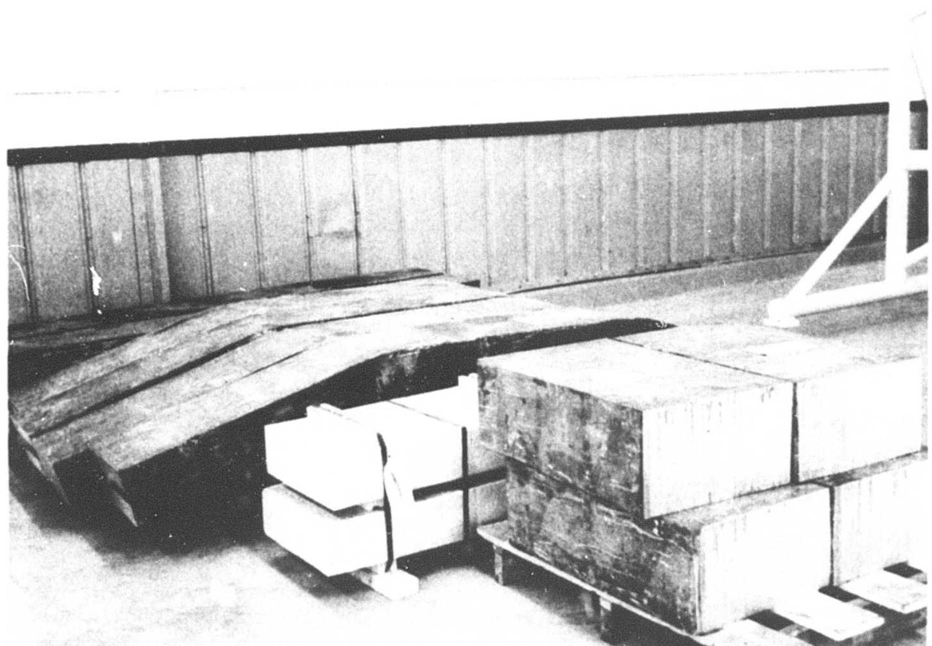

Figure 11 Wing Spar Aluminum Billets

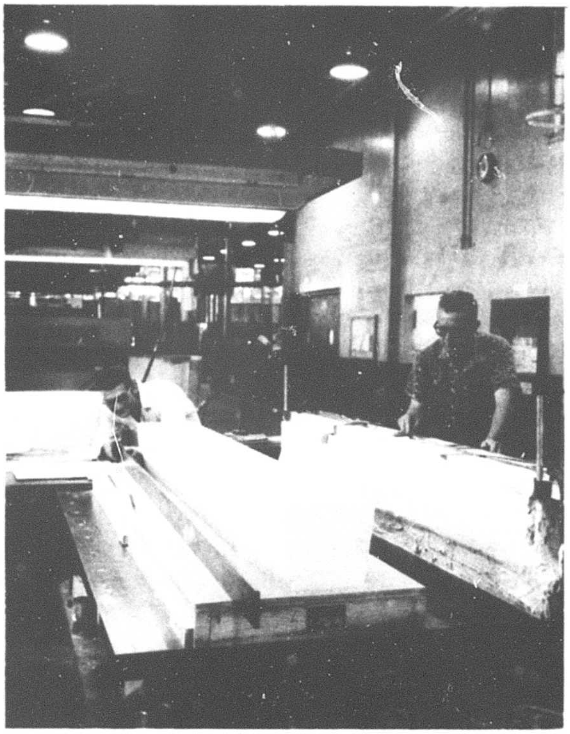

Figure 12   Wing Spar Master Patterns

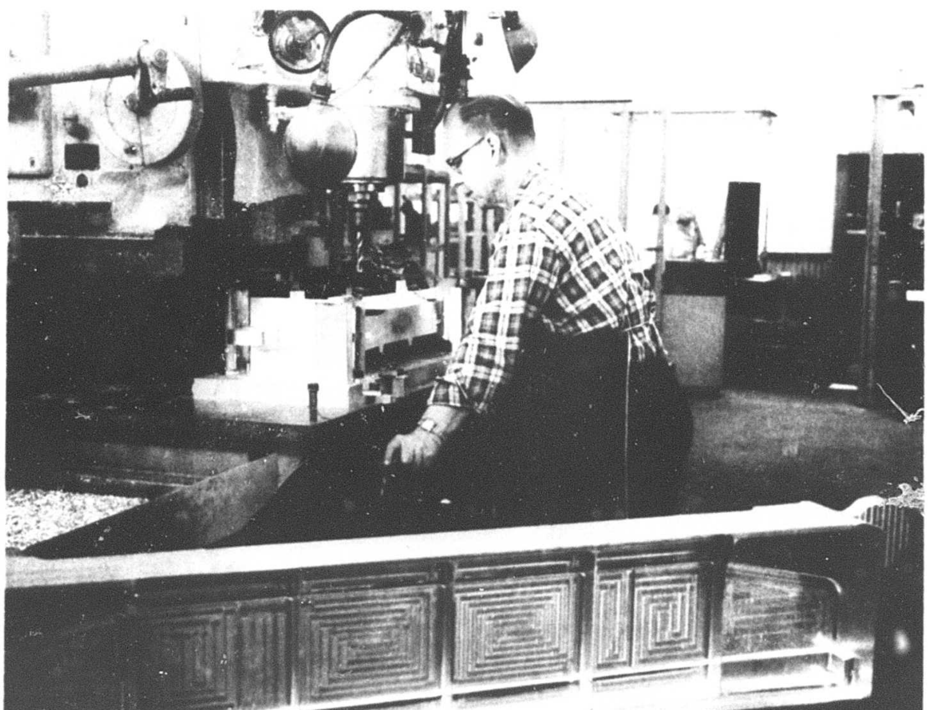

Figure 13   Fuselage Spar Finish Machining

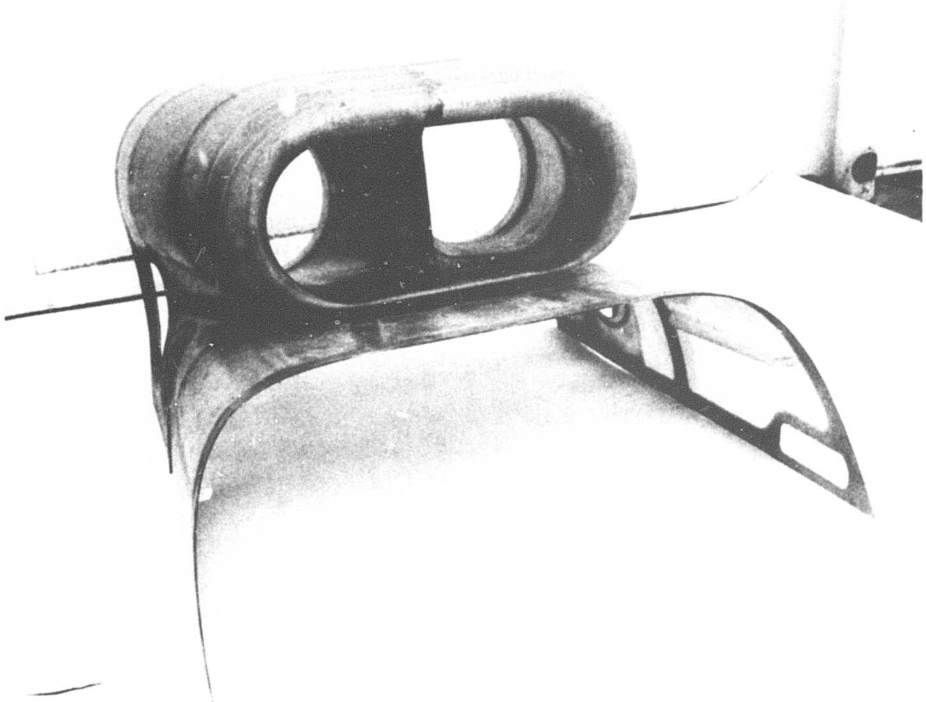

Figure 14 Engine Inlet Outer Shell

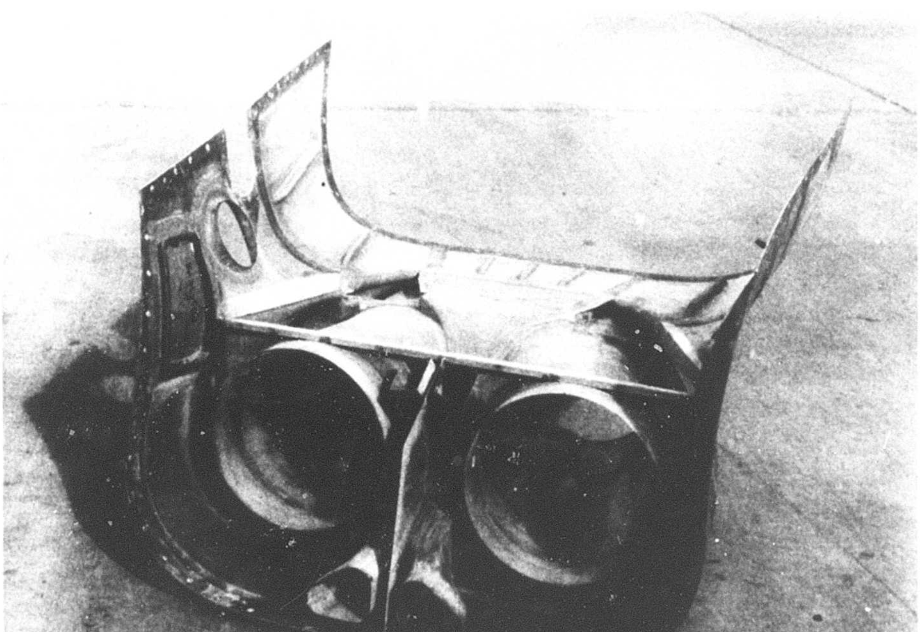

Figure 15 Engine Inlet Assembly

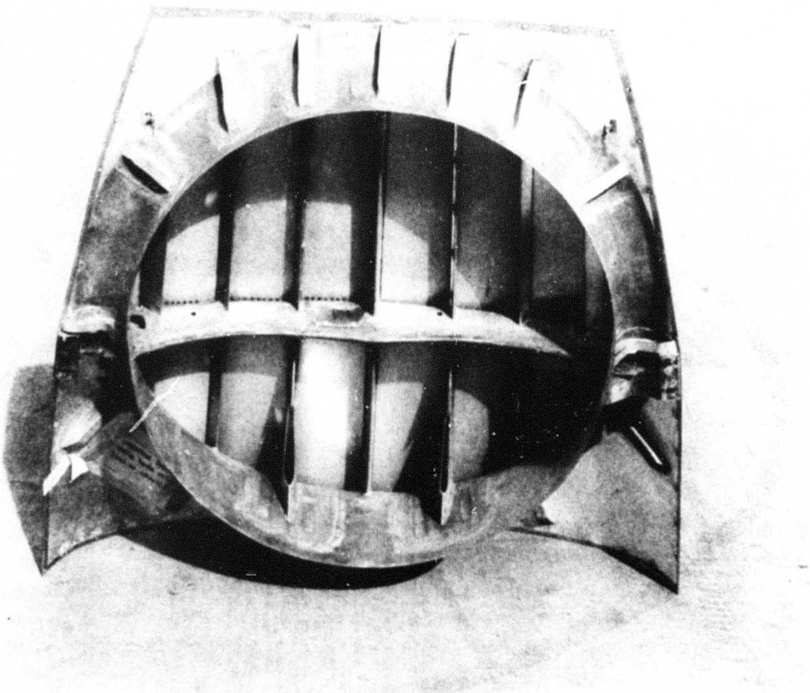

Figure 16 Pitch Fan Inlet Duct

Figure 17 Plastic Assembly Plater Master

Figure 18 Cockpit Canopy

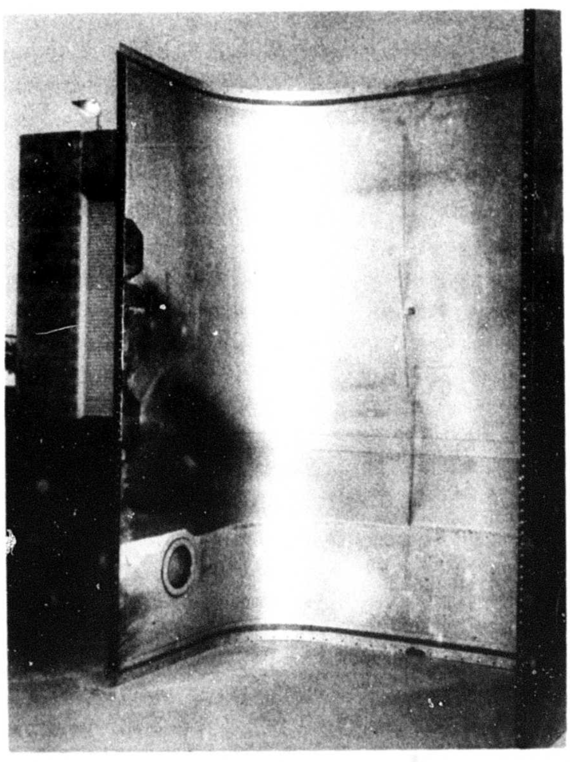

Figure 19 Engine Cover Fairing

3.1.4 Use of Titanium

Another contribution to weight saving in the XV-5A construction was the use of titanium. The pitch fan reverser doors, shown in Figure 20, required extremely high rigidity to withstand the inertial forces during door operation. They also required minimum weight due to control feedback forces. Chem-milled titanium end plates were fastened to the upper and lower titanium skins. Panel stiffness was provided by two titanium spars and seven titanium ribs. The outside skin was spotwelded to the ribs and end plates, with the inside skin blind riveted. Great skill was required during the assembly of these doors to prevent weld and rivet distortion.

Titanium was also used for the inboard underwing panels, between the spars and the wing fans. These panels, shown in Figure 21, represent another example of chemically-milled titanium.

3.1.5 Mixer Box

The XV-5A mechanical mixer box sums and proportions the pilot's controls to provide proper input to the wing fan and nose fan controls. For light weight, the mechanical mixer box frame was machined from magnesium plate, (Figure 22). Bellcranks and push rods within the mixer box were also fabricated from magnesium to reduce pilot stick forces caused by control inertias (Figure 23). The completed mixer box ready for assembly is shown in Figure 24. One of the important contributions to the XV-5A success was the development of this unit, which mechanically phased all fan controls in the proper relationship through a series of bellcranks and push rods without causing undesirable stick forces.

3.1.6 Space Frame

Early in the design of the XV-5A, it became apparent that a semi-monocoque construction for the center fuselage at the wing juncture was not practical because of required strength and propulsion system accessibility. To resolve this problem, Engineering devised a tubular framework structure, commonly called a space frame. The use of maraging steel caused serious difficulties during manufacture because of this choice of material. Maraging steel was utilized in order to reduce weight over the more commonly used steels.

Figure 25 shows the space frame in the final welding process. The massive jig was utilized to maintain precision accuracy of the space frame

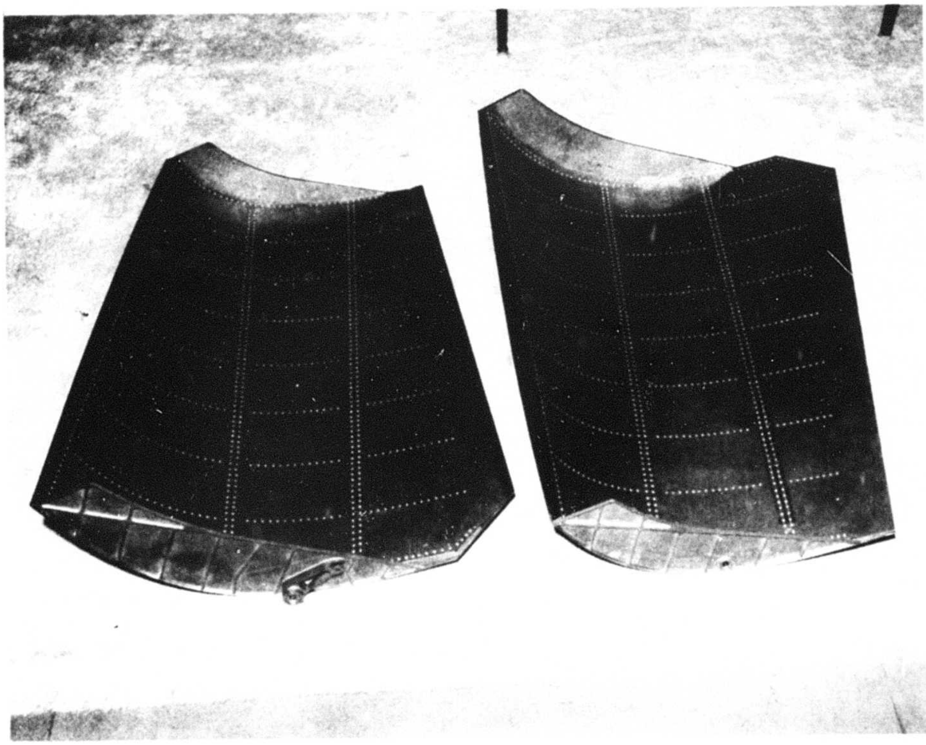

Figure 20 Titanium Pitch Fan Doors

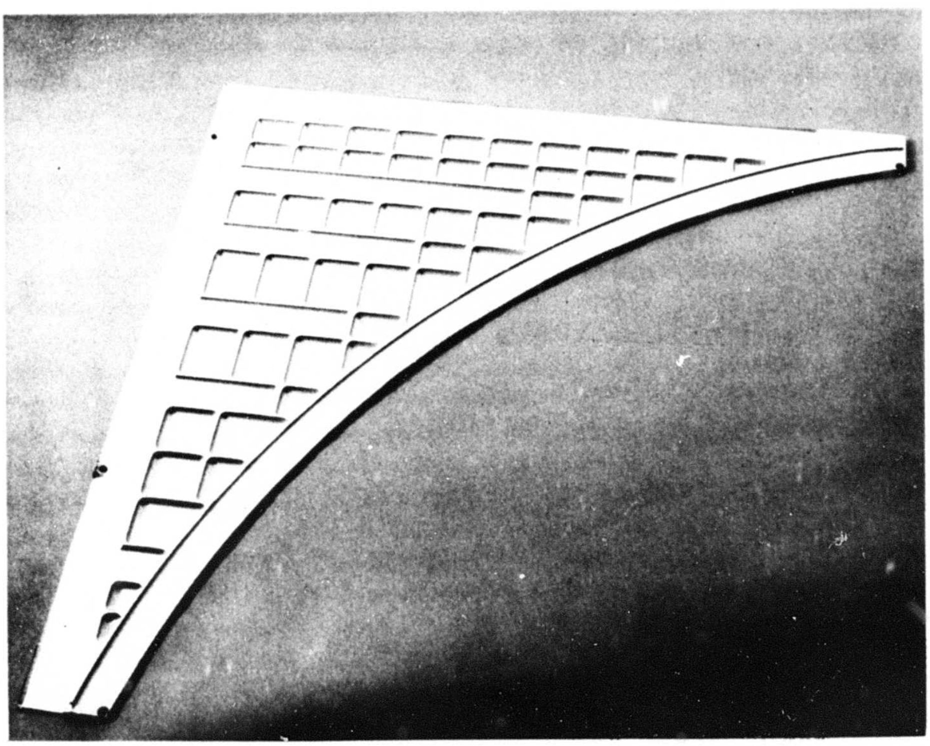

Figure 21 Titanium Underwing Panel

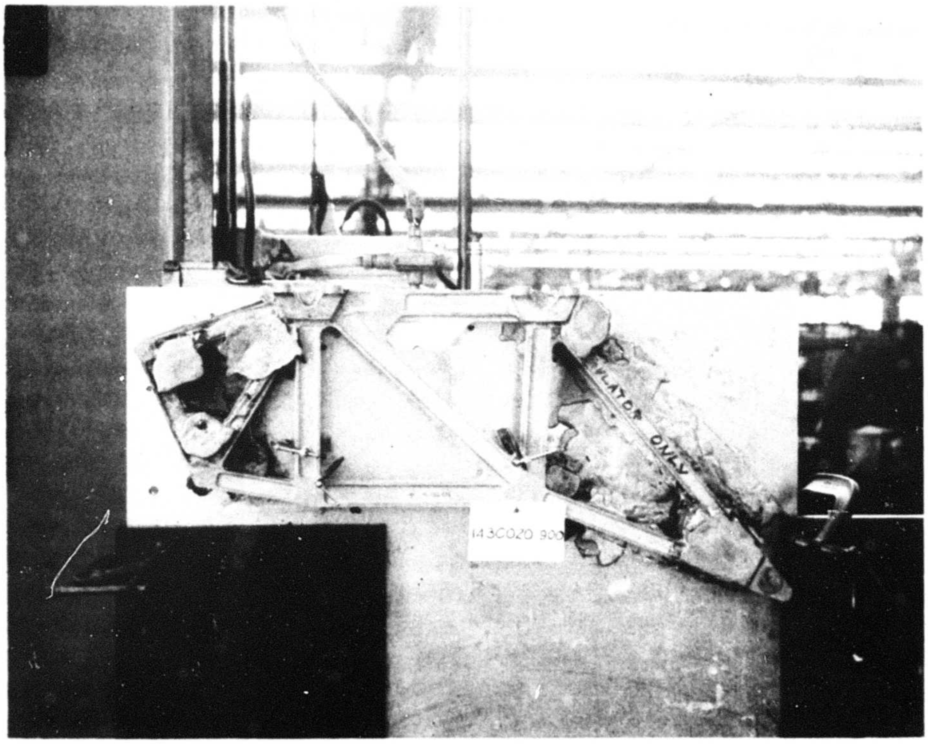

Figure 22 Mechanical Mixer Box Frame

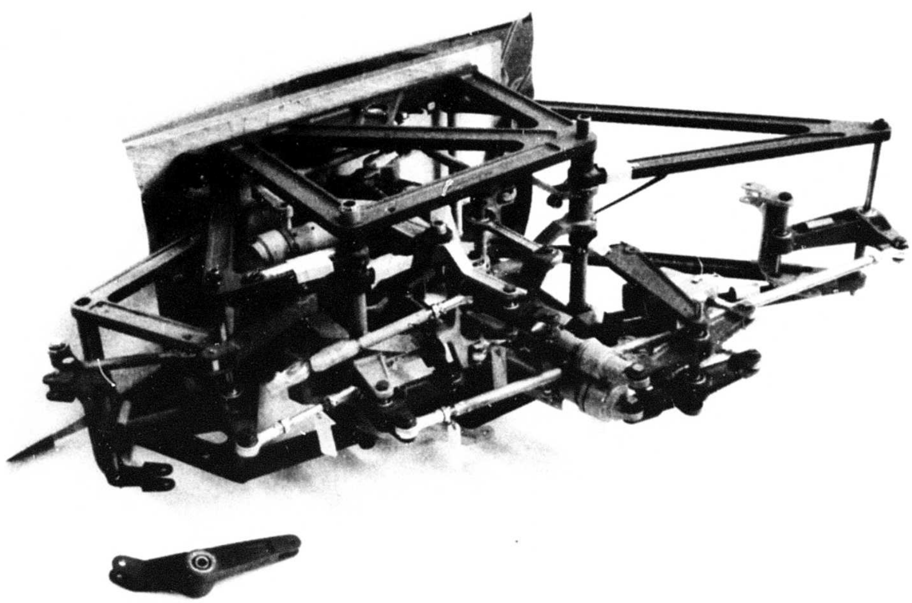

Figure 23 Mechanical Mixer Box Assembly

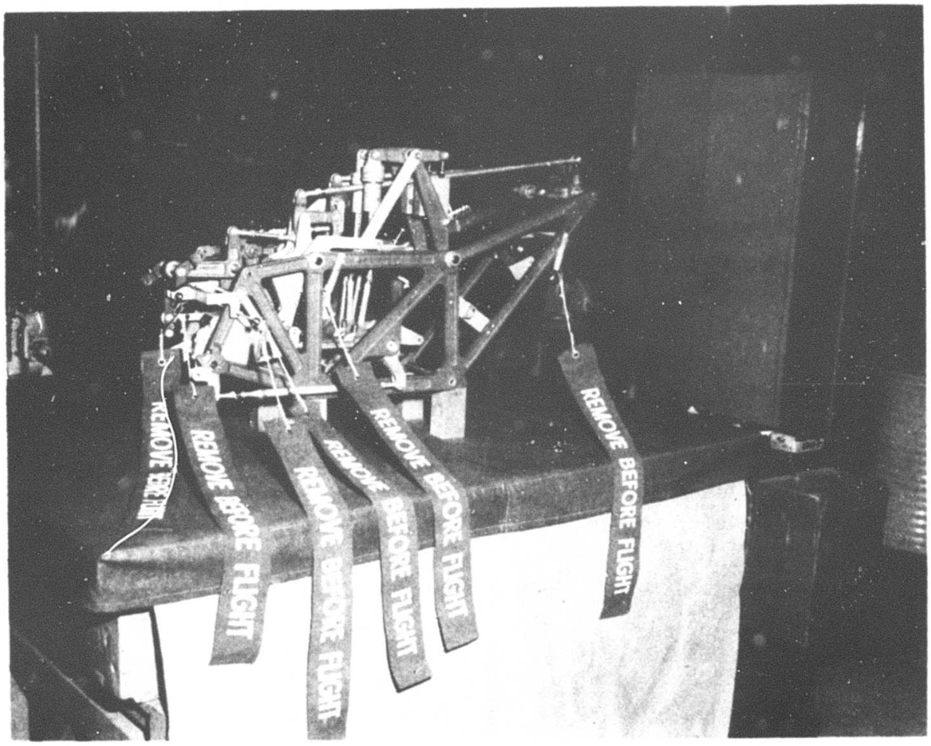

Figure 24 Completed Mechanical Mixer Box

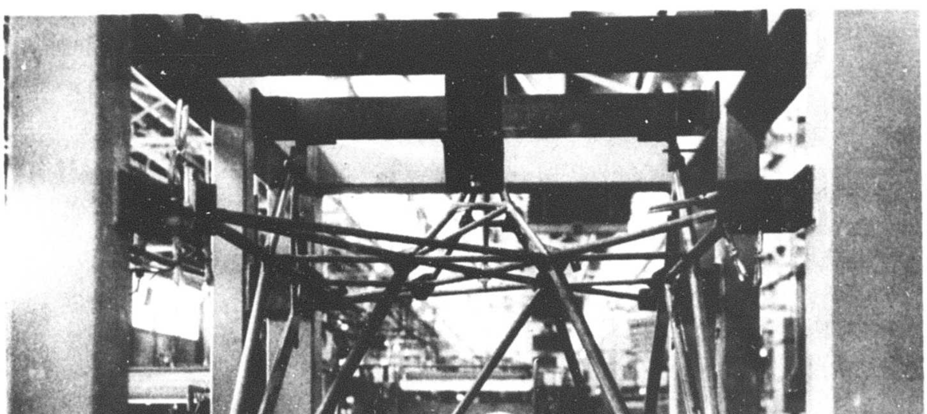

Figure 25 Space Frame Welding

attach fittings. The unit was then placed in a restraining jig, (Figure 26) and heat treated. After heat treating, the attach flanges were machined and drilled to match interface points of the forward and aft fuselage. Gold plating was applied to the space frame to reduce soak-up heating during fan mode operation. After completion of this very difficult assembly, it was concluded that the weight reduction attained by utilizing maraging steel did not justify the difficulties encountered during fabrication.

3.1.7 Cross-Over Ducts

The cross-over ducts provided a considerable challenge to the Manufacturing Department. Each skin panel was drop hammer formed and assembled into a primary weldment, (Figure 27). The ducts were then welded to the bellows and flange subassemblies, with the required stiffeners, as shown in Figure 28. The cross-over ducts, as well as the pitch fan bleed ducts, were fabricated from 19-9 corrosion-resistant steel. Because of the numerous cross-over duct and airframe/propulsion system interface points, it was necessary to locate the bellows to the primary weldment on the aircraft. After they were located, the cross-over ducts were removed from the aircraft and welded. Figure 29 shows the cross-over ducts being pressure tested after completion.

3.2 FABRICATION OF ELECTRONIC AND ELECTRICAL EQUIPMENT

3.2.1 Electronic Equipment

In addition to aircraft manufacture, Ryan designed and fabricated the major electronic units for the XV-5A airplane.

The stability augmentation amplifier was packaged as shown in Figure 30. This unit consists of two independent amplifiers, one of which has output variation capability. The unit was designed, fabricated and tested by the Ryan Electronics facility.

3.2.2 Electrical Conversion Control

This control sequences the aircraft functions during conversion from jet to fan mode, and fan mode to jet mode. Figure 31 shows the sequencer ready for installation in the aircraft, and Figure 32 shows the unit with the cover removed. The five units on either side are time delay relays. The control incorporates a complete failure indicating interlock system, which precludes conversion if there is a malfunction within the controller.

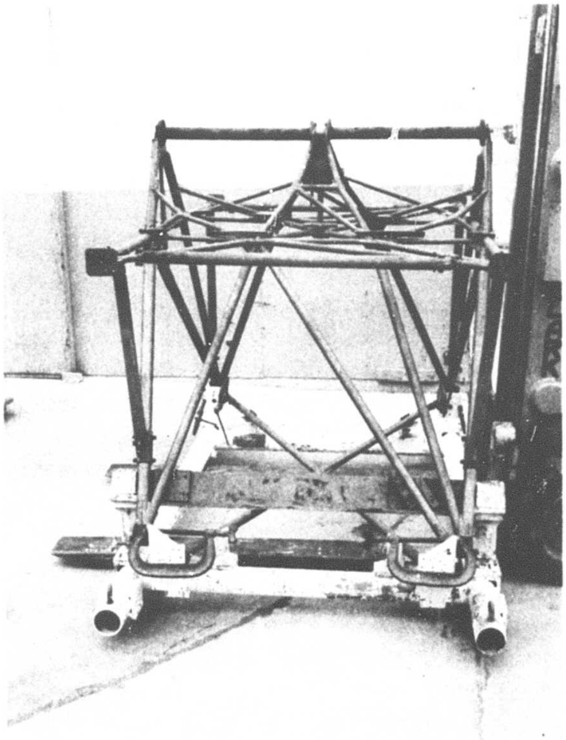

Figure 26 Space Frame in Heat Treat Fixture

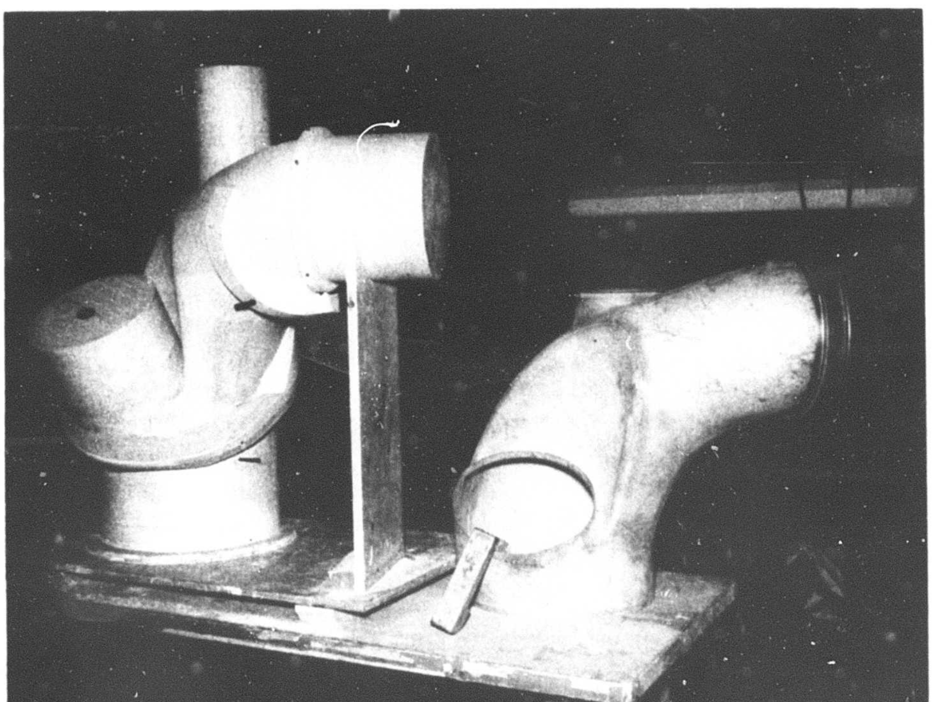

Figure 27 Crossover Duct Primary Weldment

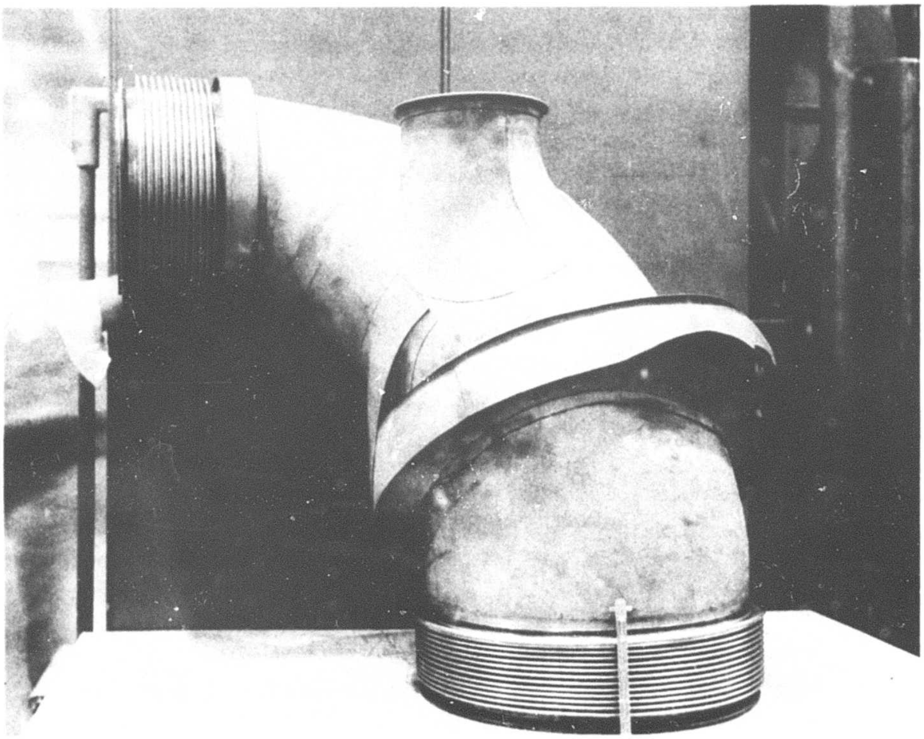

Figure 28 Crossover Duct Assembly

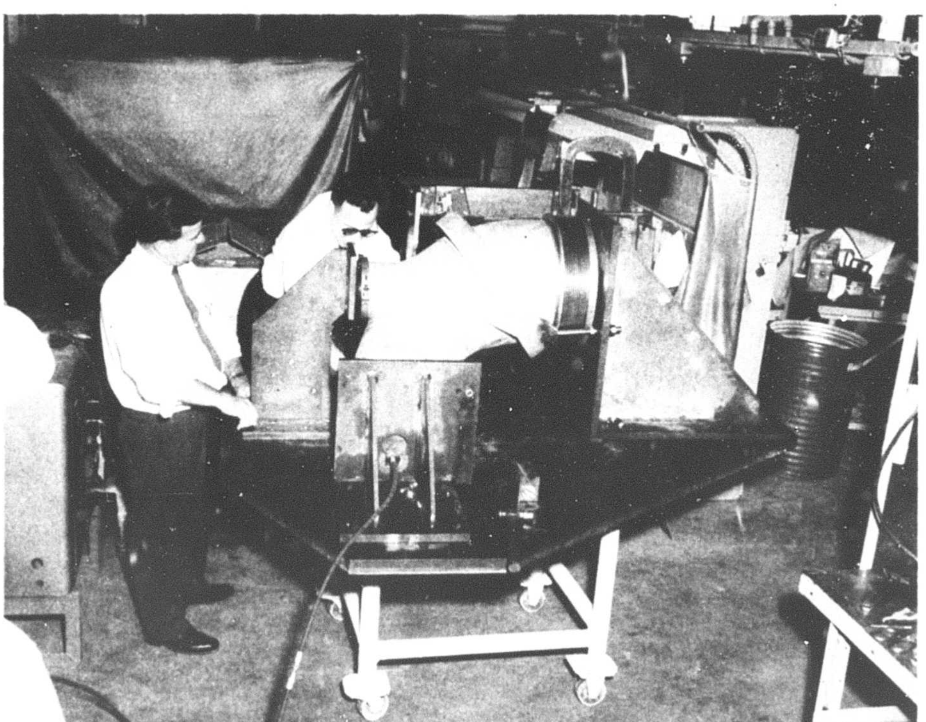

Figure 29 Crossover Duct Pressure Test

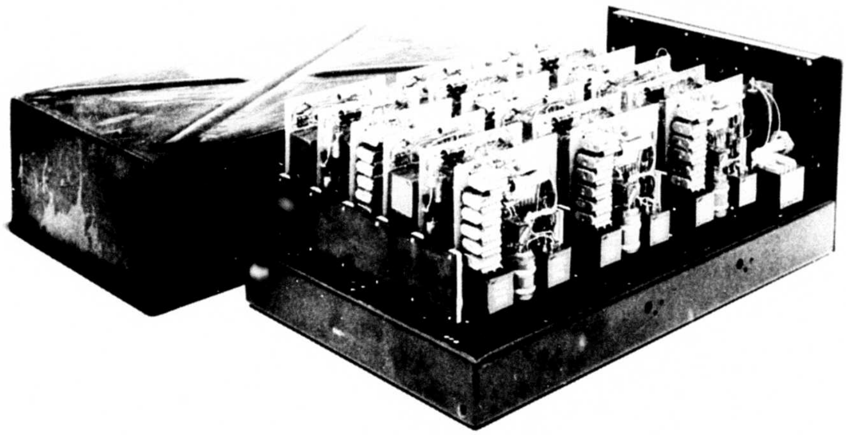

Figure 30 Stability Augmentation Amplifier

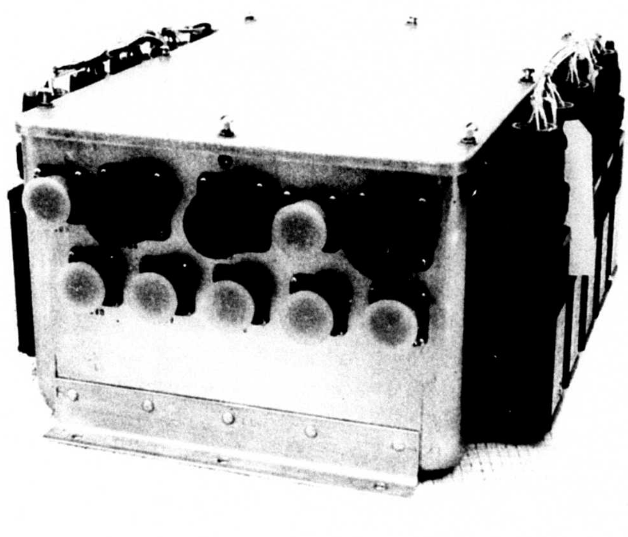

Figure 31 Electrical Conversion Control Sequencer

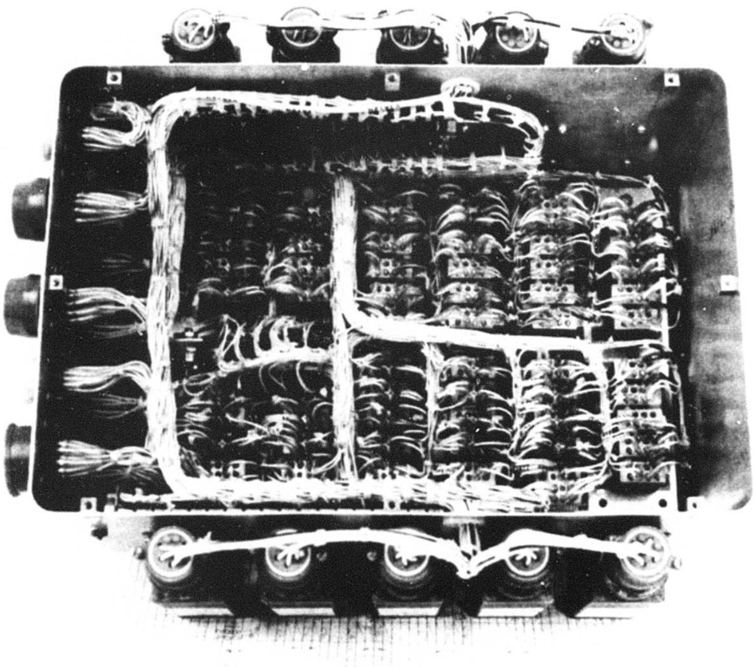

Figure 32 Electrical Conversion Control Sequencer

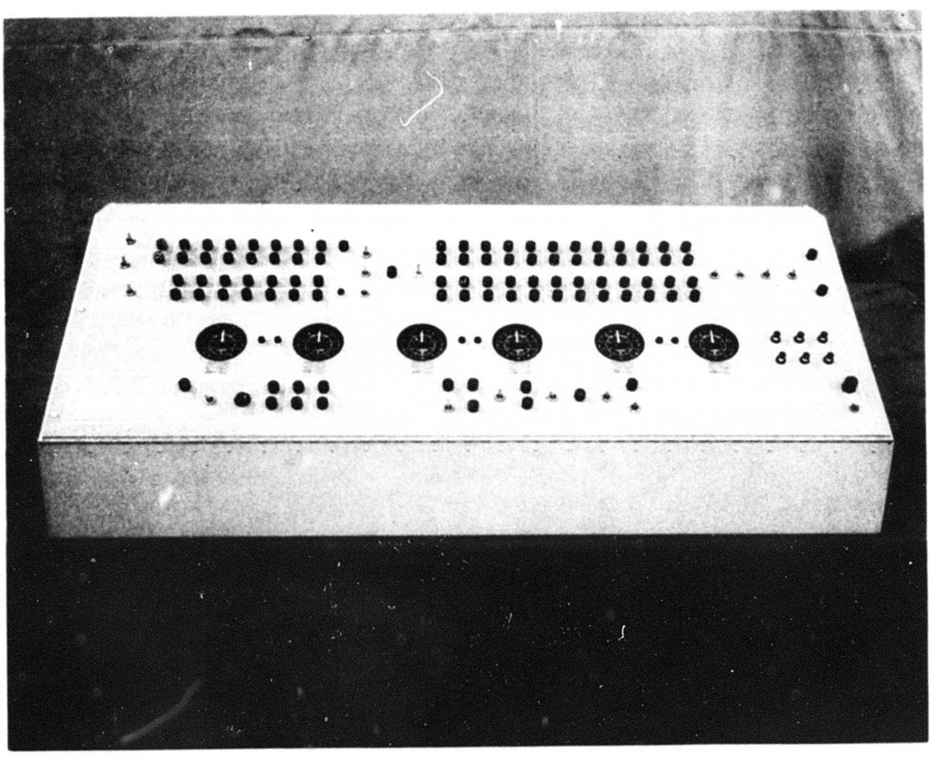

Figure 33 Checkout Console

In order to rapidly check out the electrical sequencer system, Ryan designed and fabricated a ground support checkout console, (Figure 33). This unit is plugged into the aircraft system through an umbilical cord for rapid failure analysis or periodic checks.

3.2.3 Signal Conditioner

Ryan designed and fabricated the signal conditioner box in the service acceptance configuration. This unit transcribes the instrumentation transducer voltage for acceptance by the pulse code modulating data acquisition system furnished by General Electric (Figure 34).

3.2.4 Photo Panel

Ryan manufacturing group also fabricated the photo panel shown in Figure 35 which was used during early flight test activities. Figure 36 shows the cover removed with the camera to the left, and the recording indicator to the right, where data and other test information were recorded by the photo panel for verification of proper system operation. After verification, the photo panel was removed.

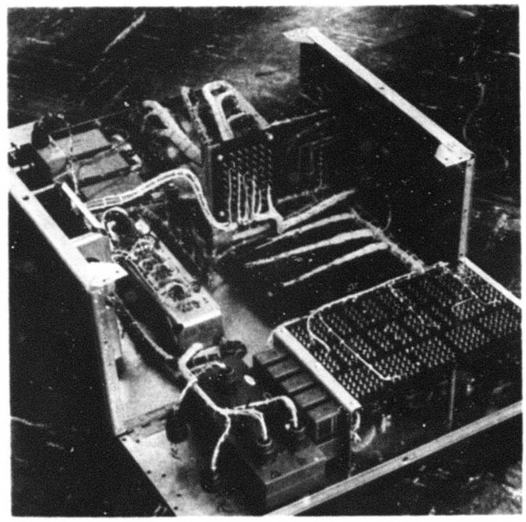

Figure 34 Signal Conditioner

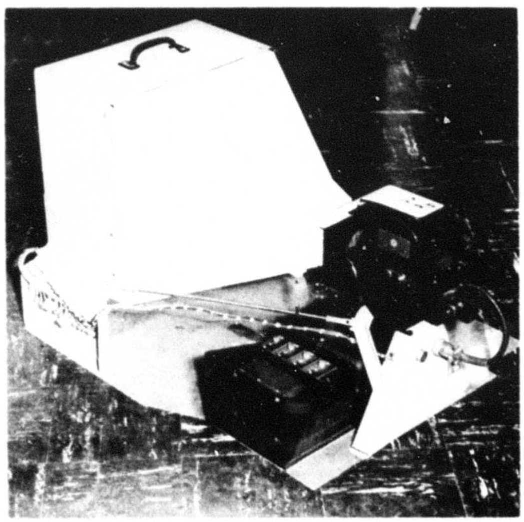

Figure 35 Photo Panel Assembly

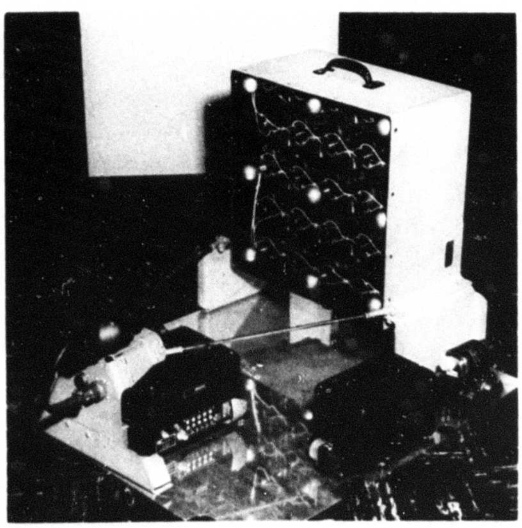

Figure 36 Photo Panel Assembly

4.0 ASSEMBLY

4.1 FUSELAGE

The XV-5A fuselage was fabricated in three major subassemblies. These were the forward section, (extending back to the forward spar), center section consisting primarily of the space frame, and aft section beginning at the rear spar.

The forward and aft fuselage sections were assembled in a large fixture indentified as a tooling dock (Figure 37). This tool contained attached scales on left and right hand sides for obtaining station position. Rails on each side provided positive waterline and buttock line identity. Detail frame and bulkhead buildups were bench-assembled utilizing loft boards for assembly dimensional control, as the frame shows in Figure 38. The completed frame appears in Figure 39. Another example is the aft fuselage frame just behind the tail pipe-to-diverter valve connection (Figure 40). As shown, the loft boards served to position locators for locating each frame detail. After each frame was completed, it was located at the proper station and waterline plane in the tooling dock (Figure 41). Frames and bulkheads were clamped to angles which were positioned transversely across the tooling dock. These angles were held in place by vertical members clamped to the primary tooling rails which ran lengthwise along the tooling dock. After a sufficient number of frames were located in the tooling dock, longerons and intercostals were assembled, thus providing a rigid tie between frames and bulkheads as illustrated in Figure 42. At this point, some of the individual frame positioning angles could be removed, since the longerons and intercostals now contributed to supporting the frames and bulkheads. Skin panels were then riveted to the fuselage frame, as in Figure 43. After completion of the forward and aft fuselage sections they were removed from the jig, (Figure 44) and positioned on mating dollies (Figure 45).

The forward and aft fuselage sections were then joined to the space frame, as shown in Figure 46, completing the primary fuselage assembly.

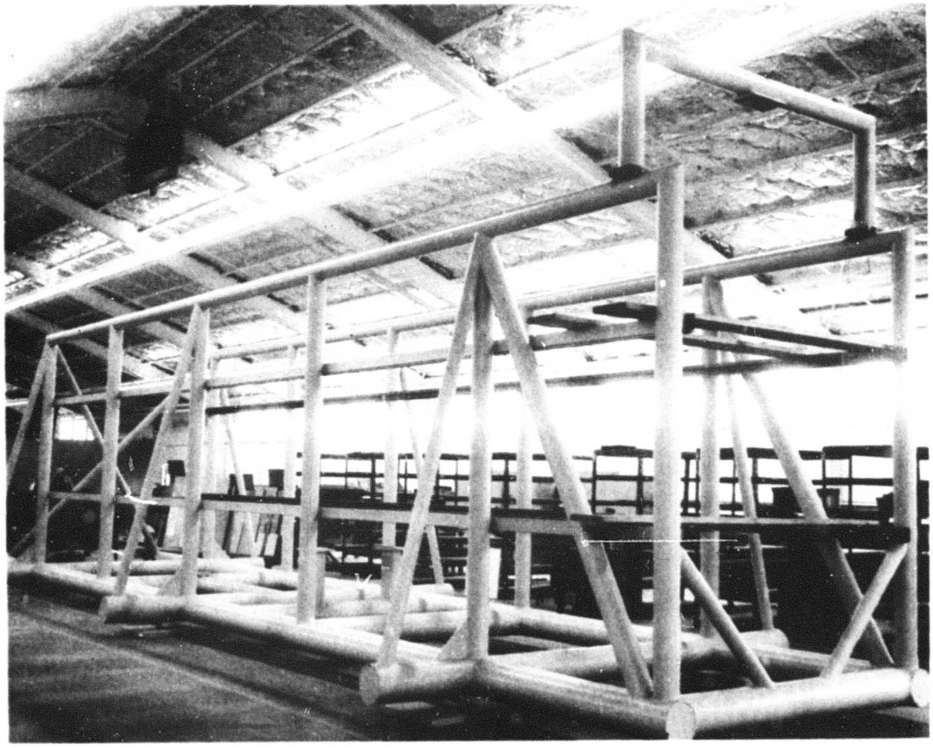

Figure 37 XV-5A Tooling Dock

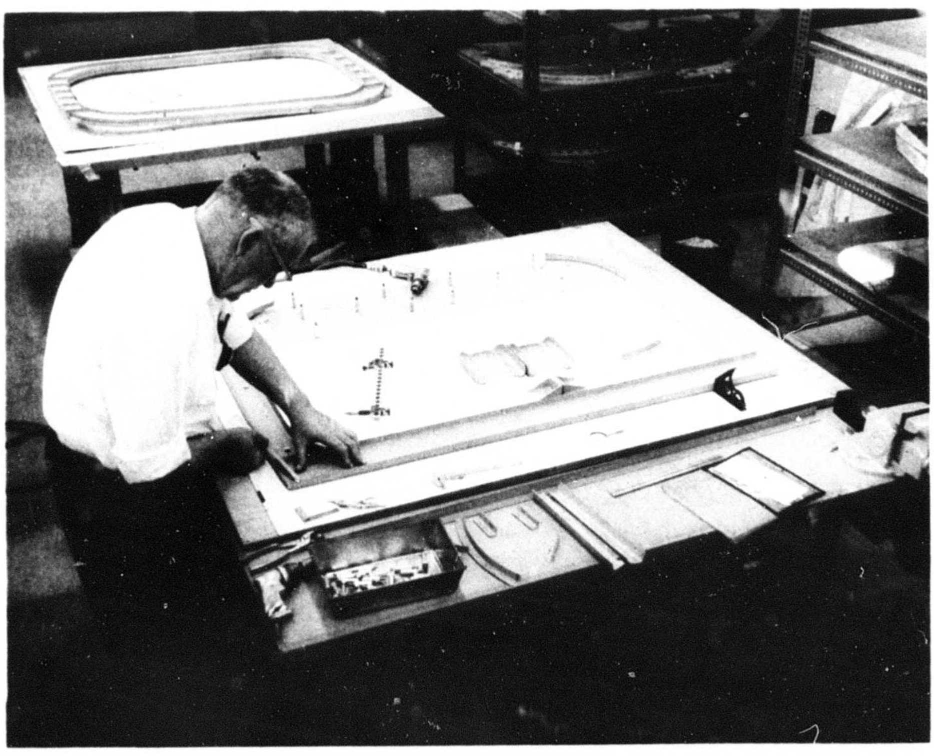

Figure 38 Frame Bench Assembly

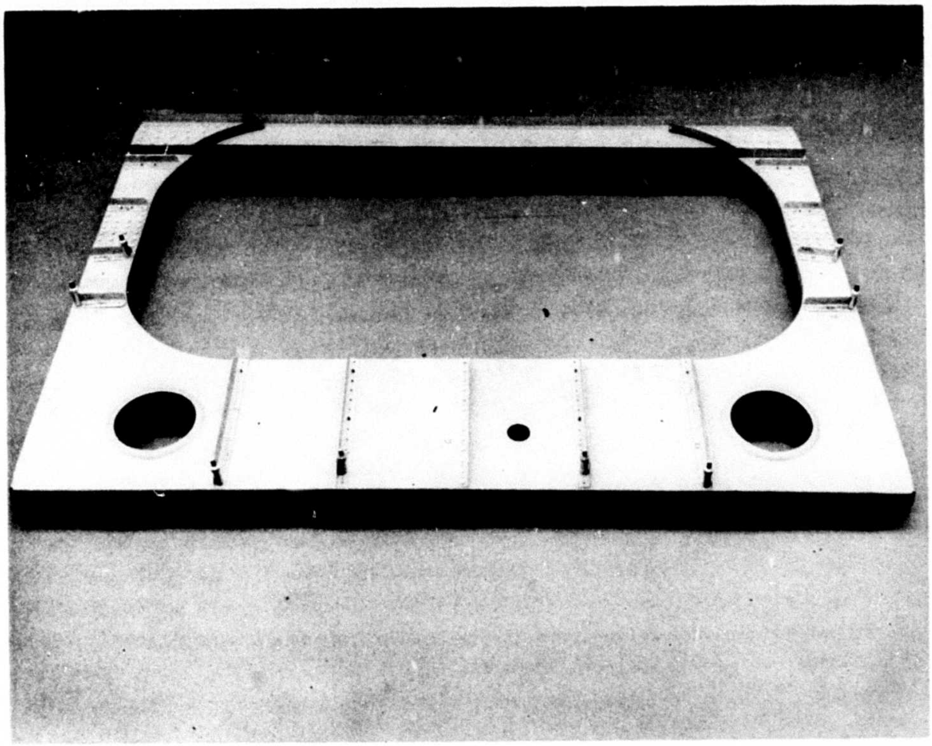

Figure 39 Frame Assembly

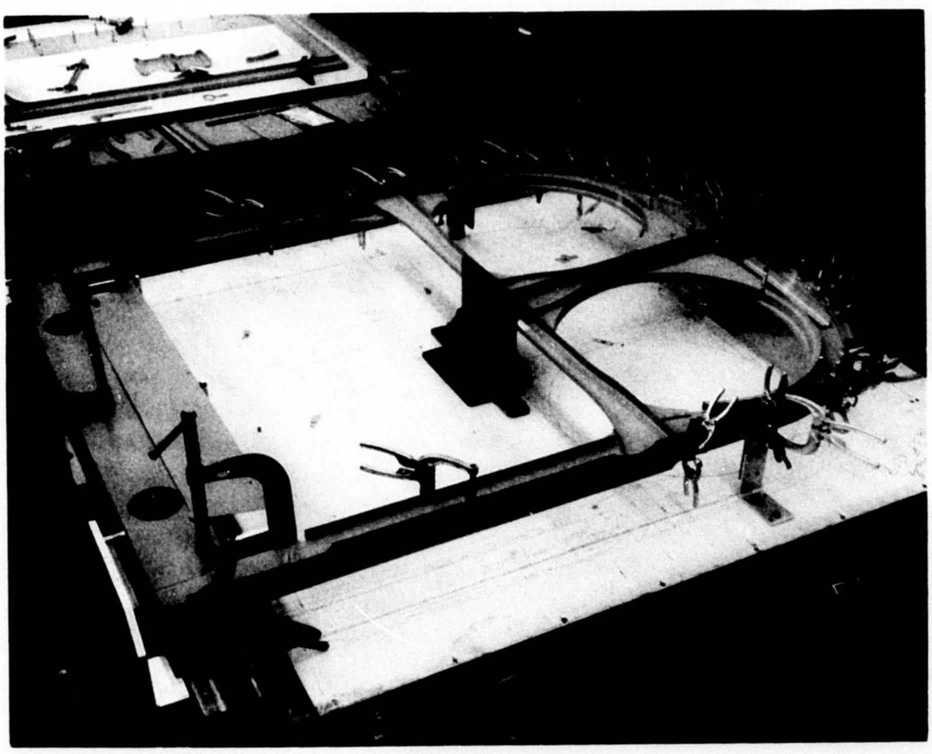

Figure 40 Loft Board Position Locator

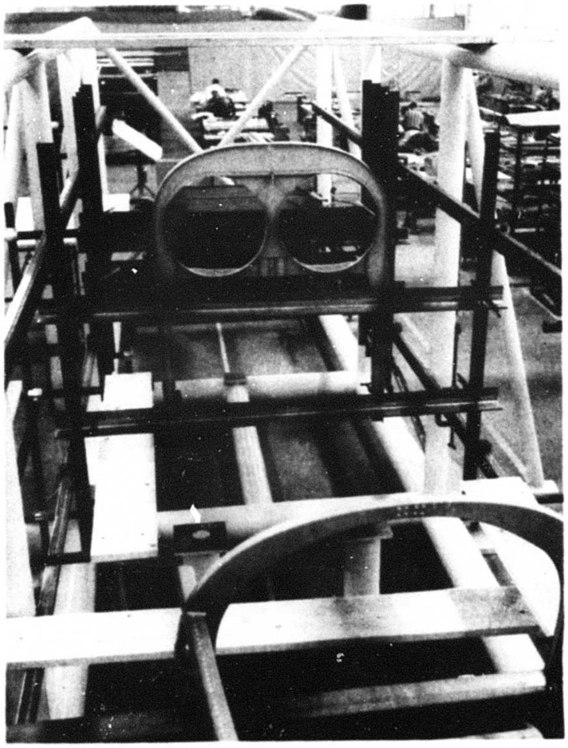

Figure 41 Frames Located in Tooling Dock

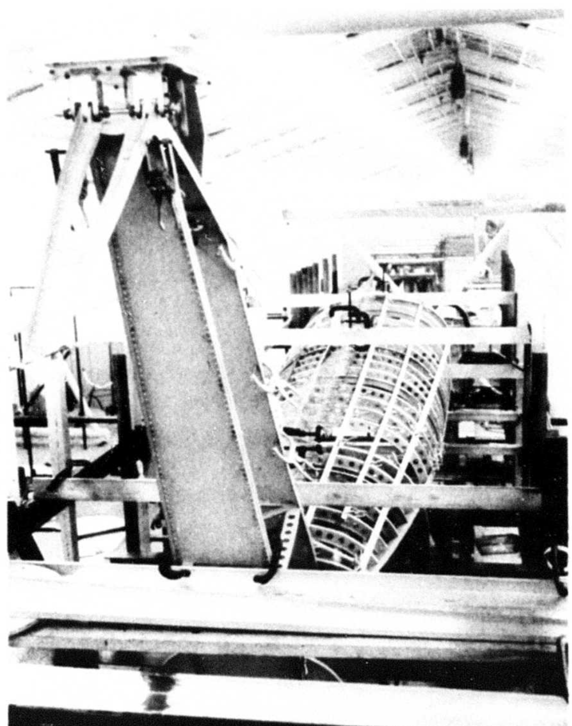

Figure 42 Fuselage Assembly in Tooling Dock

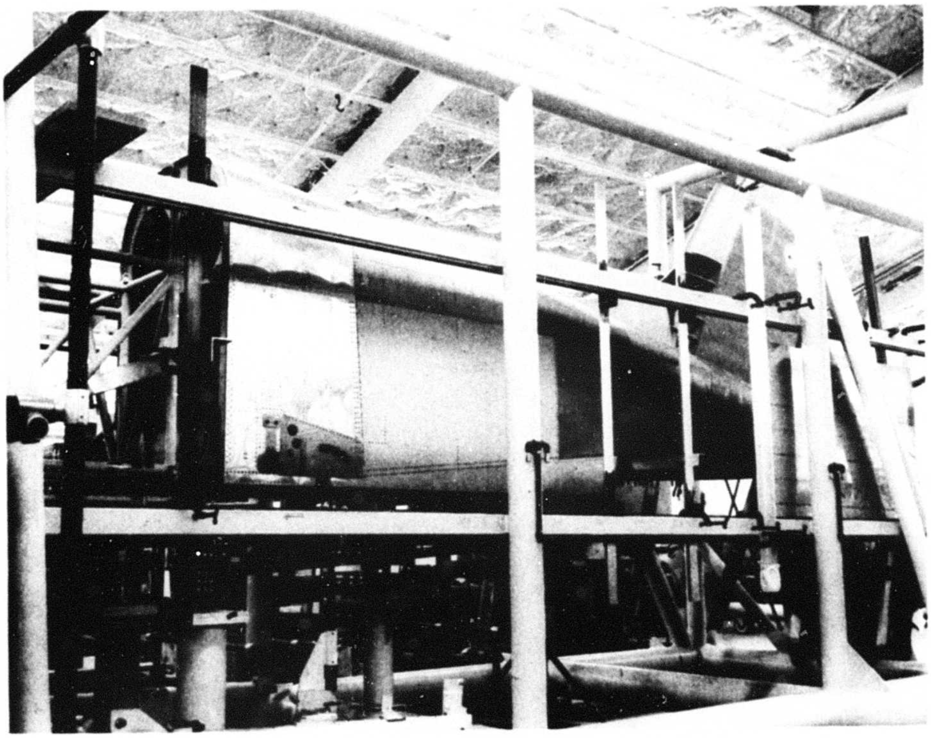

Figure 43 Skin Panel Assembly

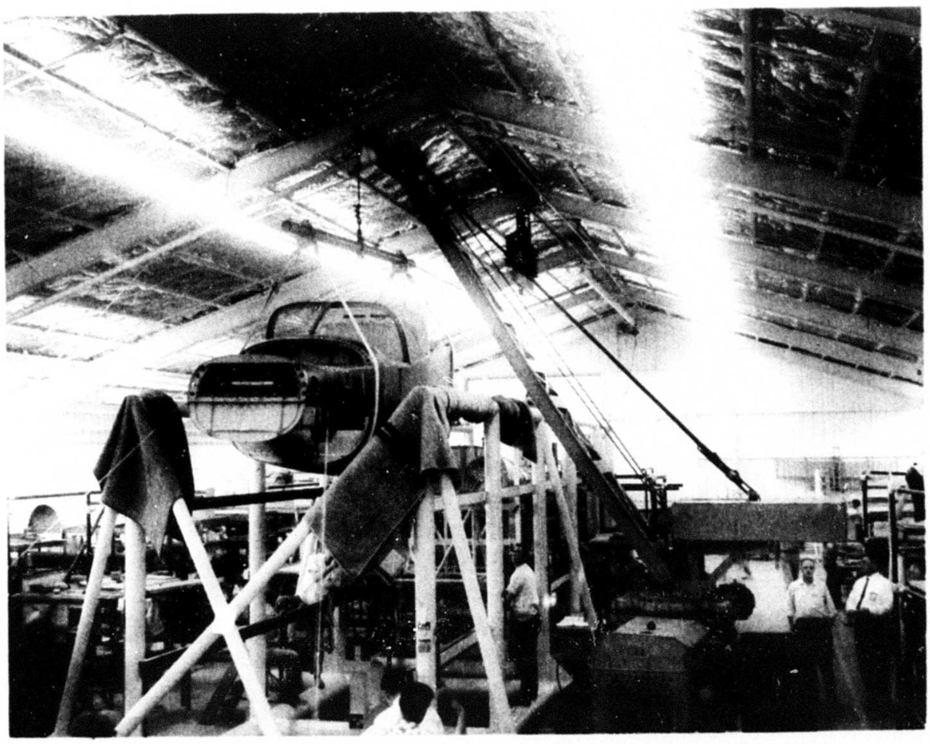

Figure 44 Removal of Completed Fuselage Section

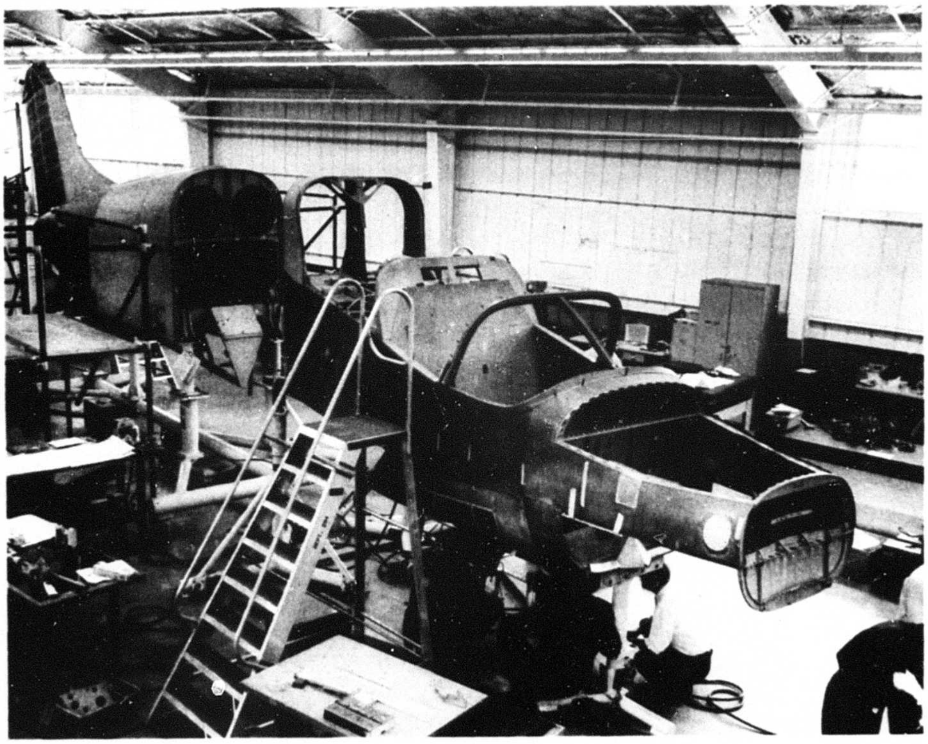

Figure 45 Fuselage on Mating Dollies

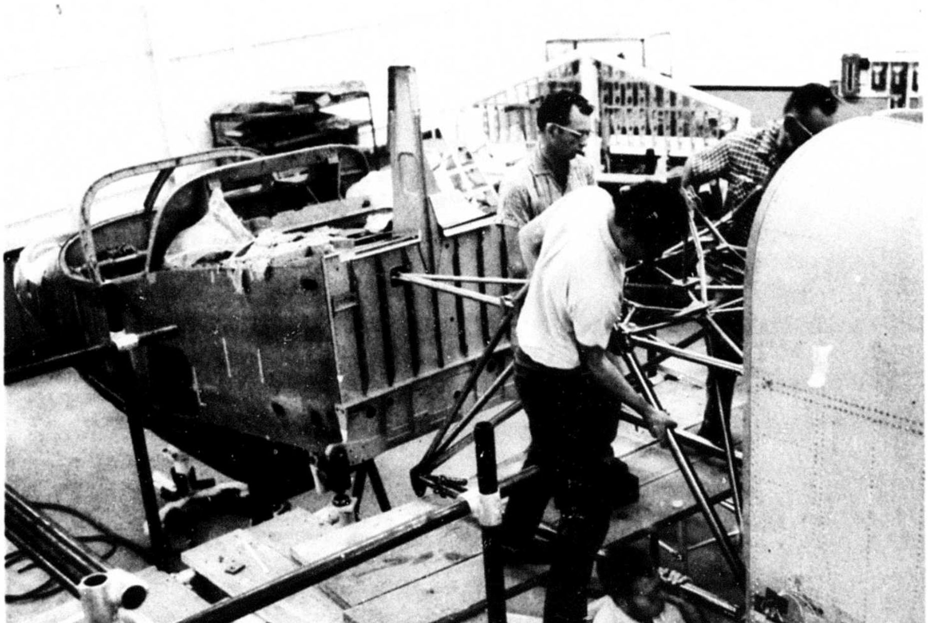

Figure 46 Primary Fuselage Assembly

4.2 WING

Each wing assembly was subassembled in generally the same manner as the fuselage. Figure 47 shows one of the wing assembly jigs. The forward and aft spars were located in the assembly jig with subsequent assembly of the ribs as shown in Figure 48. Wing skin panels were then riveted, completing primary wing assembly (Figure 49). At this stage, the wings were removed from the jig and installed on the fuselage, as shown in Figure 50. The horizontal tail was assembled in a manner similar to the wing.

4.3 SYSTEMS INSTALLATION

Figure 51 shows a wing fan being installed. The pitch fan is shown in Figure 52 prior to installation of the pitch fan inlet and louver system. The J85 engine with the diverter valve and attendant components installed was then lowered into the engine compartment, (Figure 53). Installation of the balance of the aircraft equipment was completed without any major difficulties.

The aircraft was then subjected to extensive system testing, (shown in Figure 54). Following systems tests, the aircraft was rolled out, (Figure 55), and turned over to the Ground Test Group for the installed systems functional test.

After completion of ground testing at San Diego, key manufacturing personnel and their equipment were transferred to Edwards Air Force Base to support the flight test operation. Number two aircraft was loaded on a trailer for shipment to Edwards AFB, (Figure 56), thus completing the manufacturing activities at San Diego.

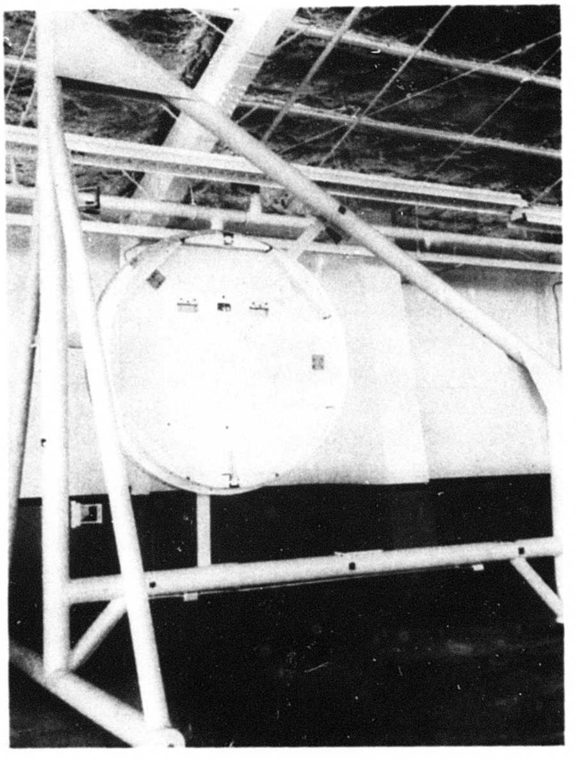

Figure 47 Wing Assembly Jig

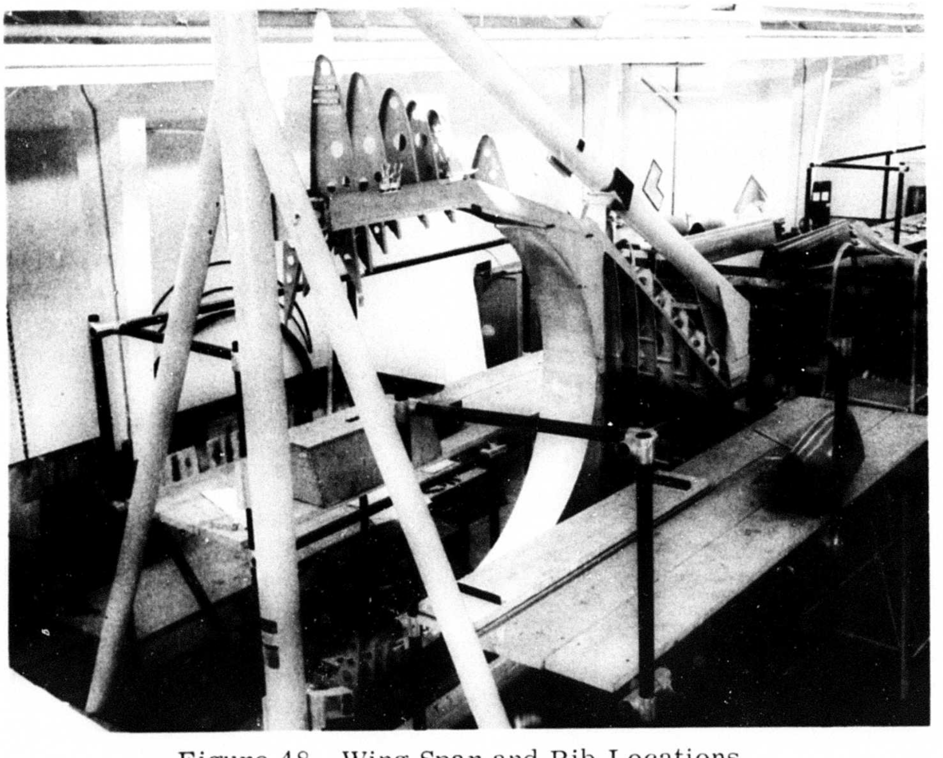

Figure 48 Wing Spar and Rib Locations

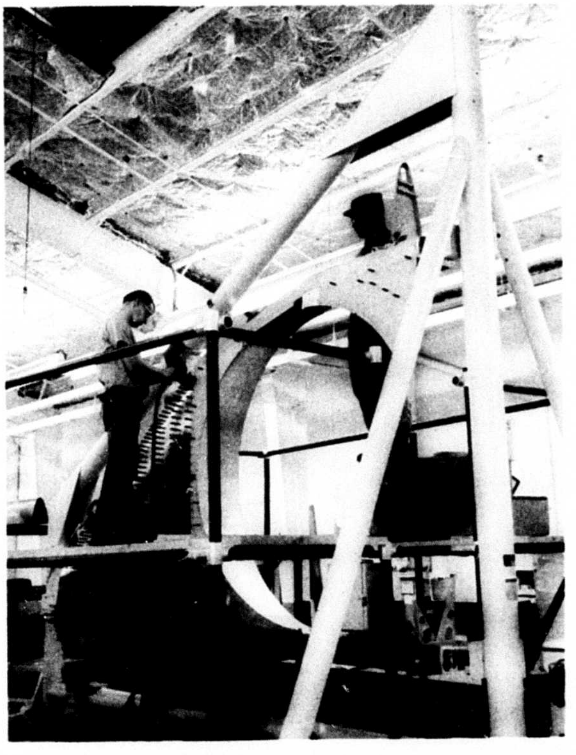

Figure 49 Wing Skin Panel Assembly

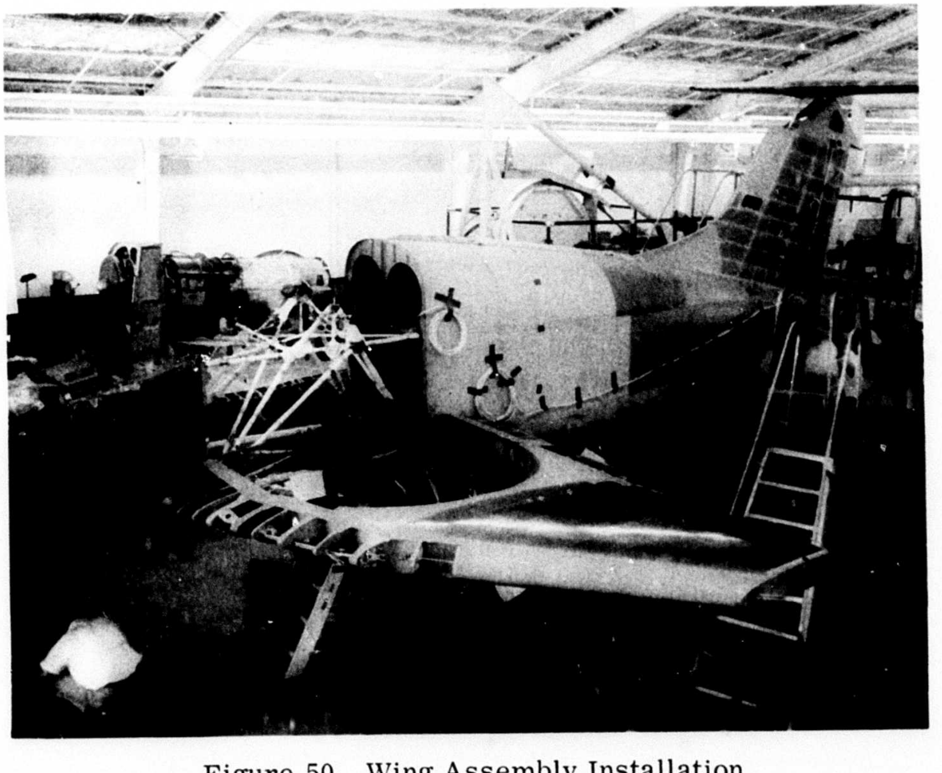

Figure 50 Wing Assembly Installation

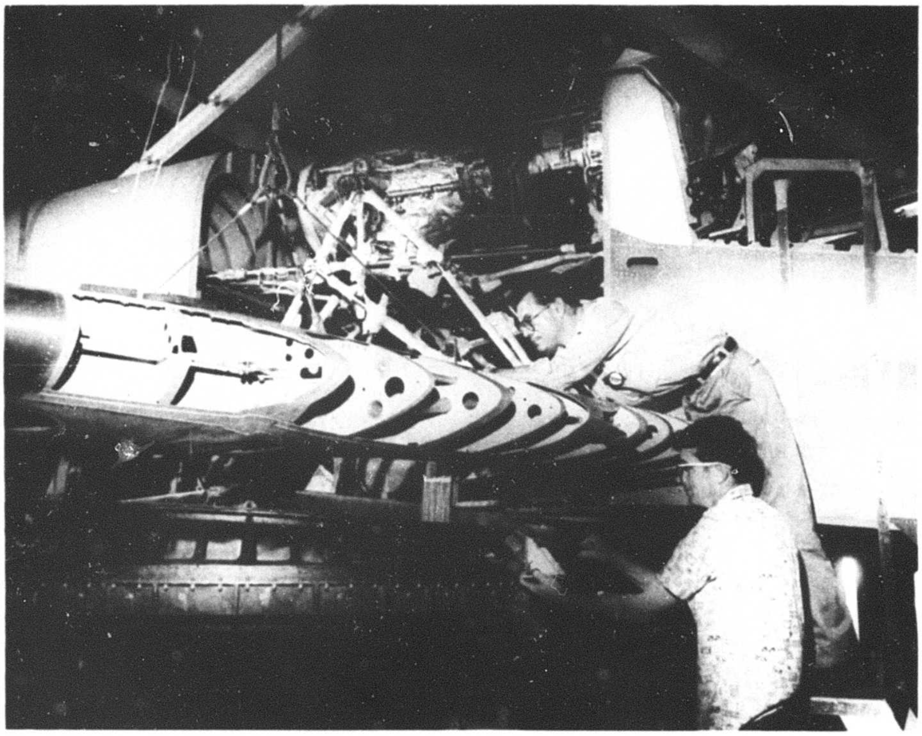

Figure 51 Wing Fan Installation

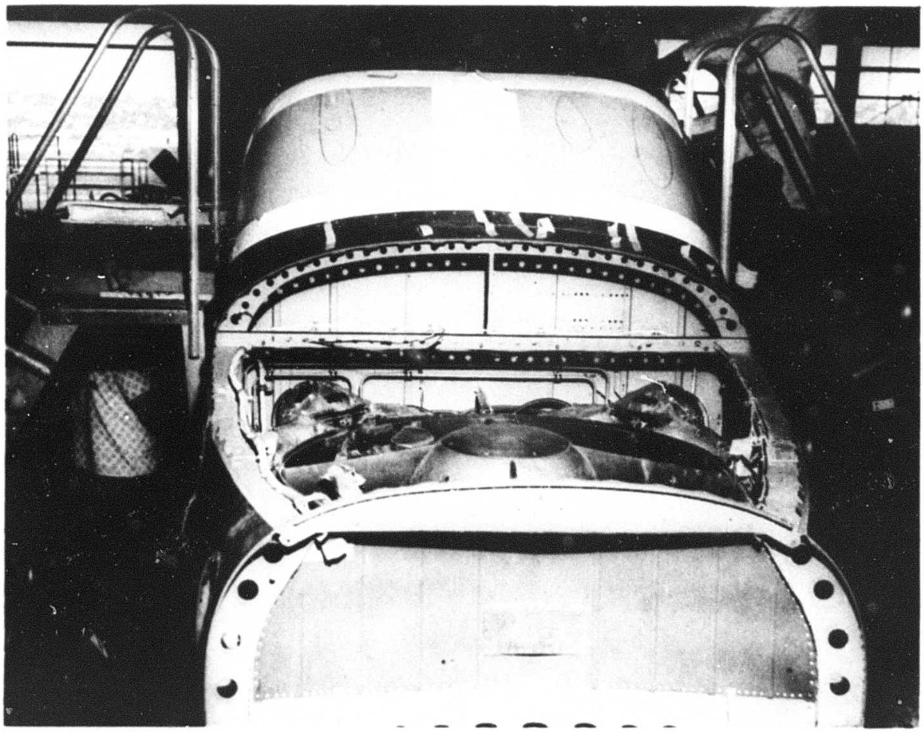

Figure 52 Pitch Fan Installed

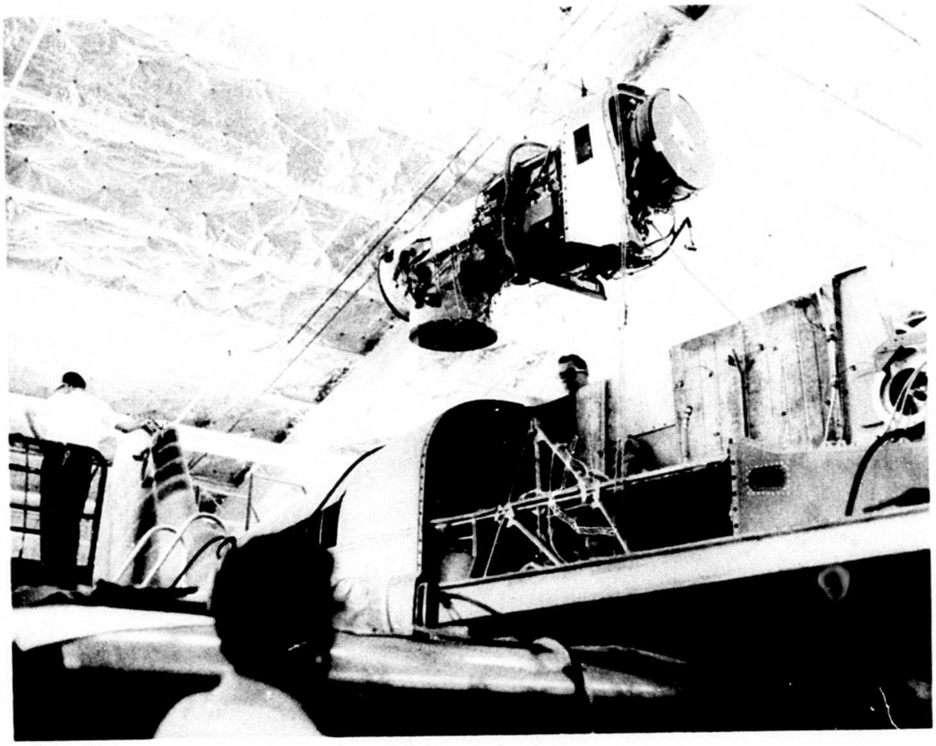

Figure 53 Engine and Diverter Valve Installation

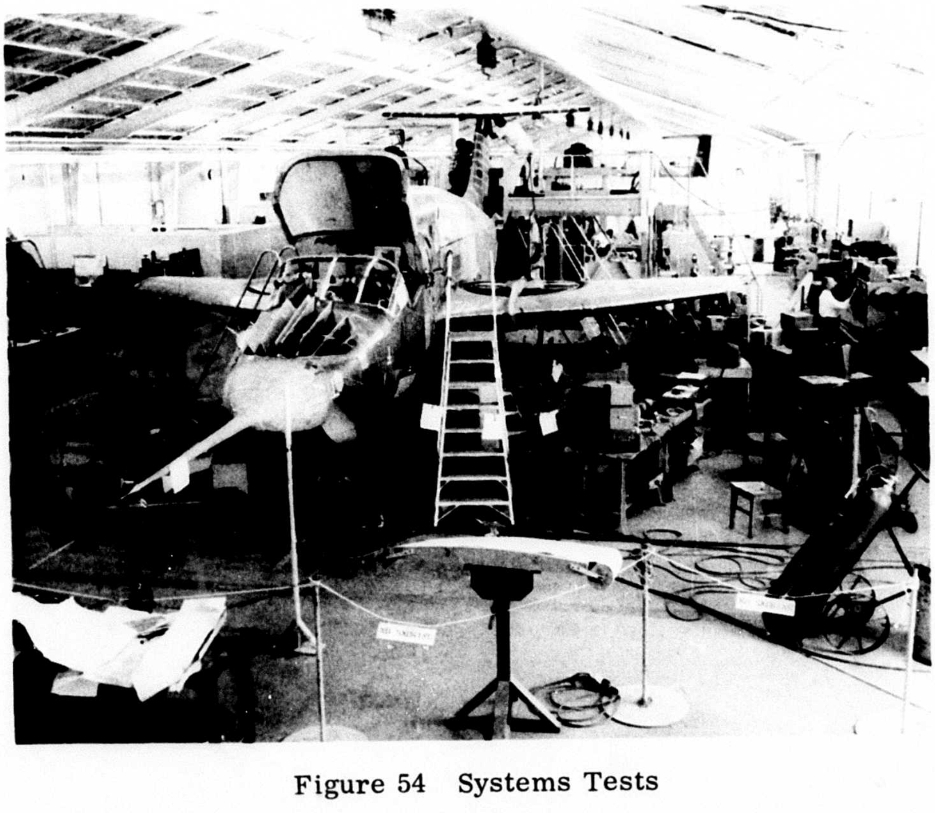

Figure 54 Systems Tests

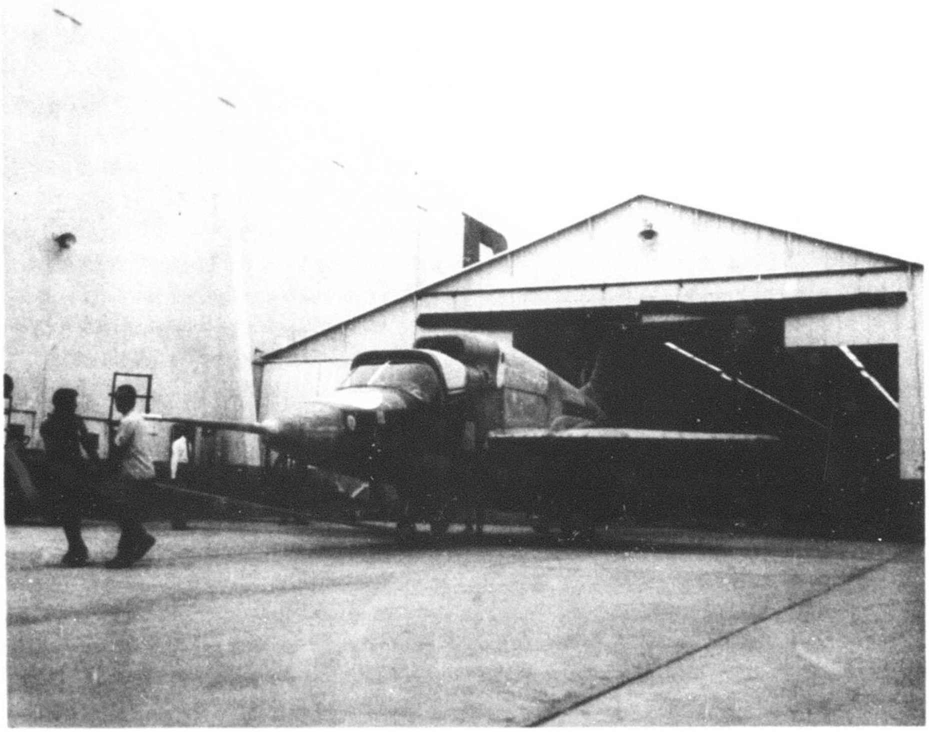

Figure 55 Rollout

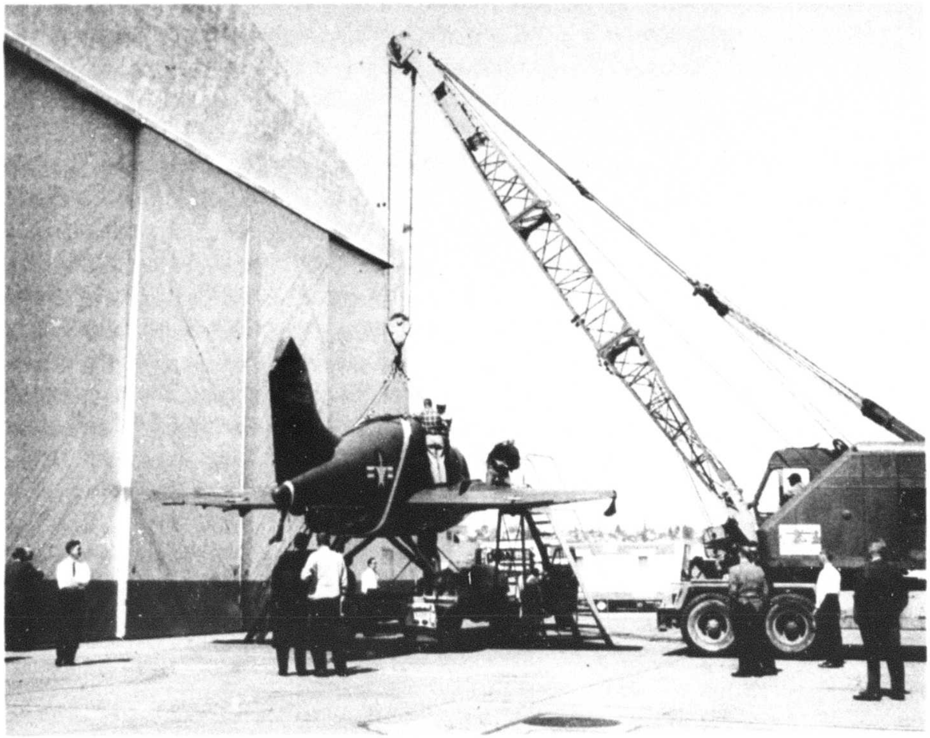

Figure 56 Loading No. 2 for Shipment

5.0 QUALITY CONTROL

Quality Control activities conducted during the manufacture of the XV-5A aircraft insured quality in the construction and testing, and as directed by the General Electric Purchase Order.

The Quality Control Program emphasized flight safety, flightworthiness, and contract conformance. The Quality Control program utilized MIL-Q-9858 and the Ryan Quality Control Product Assurance Manual as a guide. Implementation was directed toward acceptable records, and minimum formality, consistent with contract requirements.

The Quality Control function was under the direct control of the Director of Quality Control. A central Quality Control project group was established to perform all assembly and test functions for the XV-5A Program.

5.1 INSPECTION AND MEASURING EQUIPMENT

Quality Control personnel were responsible for the periodic calibration, repair and control of all test, inspection and measuring equipment, including electronic, electro-mechanical, mechanical, hydraulic, and pneumatic types. This responsibility also included the periodic testing and calibration of personal tools used on the XV-5A program.

All standards used are directly traceable to the National Bureau of Standards. Quality Control personnel monitored all equipment to assure compliance with calibration requirements.

5.2 PURCHASED AND SUBCONTRACTED SUPPLIES

In general, all purchased and subcontracted supplies were processed and controlled in accordance with the policies as outlined by the Ryan Product Assurance Manual.

Only qualified suppliers were accepted for the XV-5A program and their products were received by two methods. For standard supplies and those requiring normal receiving inspection operations, the products were routed through the regular receiving area. All other supplies were routed to the project receiving inspection area for processing. This differentiation was predetermined by special notation on the purchase requisition and the purchase order.

To expedite receiving of materials, Quality Control acceptance criteria were included in the design notes of subcontracted and purchased parts drawings as a guide to all inspection functions.

5.3 CONTROL OF IN-PROCESS SUPPLIES

The Quality Engineering Group acted as advisors to Manufacturing Control and served all manufacturing operations pertinent to this program. Quality Control issued, to the Manufacturing Department, P. Q. stamps serialized for control by the Manufacturing departments as to their use. It was the Manufacturing Department's sole responsibility to monitor the use and circumstances under which the P. Q. stamps were used. When Manufacturing determined a part was of a complex nature and should be under the direct cognizance of Inspection, it was assigned to the Inspection group. If the problem concerned tolerance, M. R. B. disposition or general interpretation, the Quality Control Engineer resolved the problem. When a part had been determined as requiring M. R. B. type action, the planning sheet was stamped "Critical" by the Quality Engineer and the parts affected were 100% inspected for all operations performed.

All parts through the regular Receiving Inspection area were processed on a 100% basis. All parts requiring heat treat were processed under a 100% inspection basis. All parts manufactured or processed in the XV-5A assembly area were serviced by a Project Inspector.

5.4 SHIPPING CONTROL

Shipping requirements were under the direction of regular shipping inspection personnel, with Quality Control guidance. This assured compliance with customer requirements, and that the products being shipped were properly processed. All records indicate that completion status was in accordance with contractual requirements.

5.5 CUSTOMER PROPERTY

Customer property was processed under Ryan Standard Procedure in accordance with Customer requirements. All incoming supplies were checked against the Customer's shipping document for compliance. Discrepancies or damage were immediately reported to the Customer for disposition.

5.6 NON-CONFORMING SUPPLIES

Rejected material or products whose disposition was scrap, were processed in accordance with Ryan Inspection Procedure (Material Review Procedure). Records are on file with the Ryan Quality Control Department.

5.7 TOOLING

The XV-5A project philosophy excluded the detailed inspection of all tools, except predetermined coordinated inspection points as required by the tool order. The inspection emphasis was concentrated on the engineering envelope or attach points.

Quality workmanship was the direct responsibility of the Tooling Department. Shop work orders approved by the use of P. Q. stamps, except for inspection requirements as noted on the tool order.

The Quality Control Inspector's stamp on the tool tag attached to the tool or fixture signified acceptance of the tool or fixture, although conformance was with the engineering envelope or attach points.

Tools and gages used by Manufacturing and Quality Control assured accuracy, quality, reliability and interchangeability (where required), through careful inspection, calibration and surveillance of all tools.

Inspection precision measuring tools (both Company and personal), were registered and periodically checked to masters to certify their accuracy.

5.8 EVIDENCE OF APPROVALS

Quality Control maintained records of all objective evidence used in the fulfillment of the XV-5A contract.

This material includes the Engineering Changes, Aircraft Inspection Log Books, Special Tests, Qualification Testing, and others.